

A force-theoretic framework for event structure

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Despite the very significant advances in understanding the semantics of eventualities since the Davidsonian revolution, the representation of Accomplishments in *ceteris non paribus* contexts where the telos is not reached remains problematic. In this paper we propose that non-culminating or defeasible cases of Accomplishments are the base case in a reconceptualized semantics for event structure. The core concept that we use in our reconceptualization is 'force', an input of energy that arises from the objects and properties in a situation. This approach cashes in the intuition behind the traditional concept of dynamicity, which has been an important descriptor in event semantics but which has not usually been expressly encoded in model-theoretic accounts of the syntax/semantics interface. Force arguments replace event arguments in dynamic predicates, and situation arguments replace event arguments in stative predicates. The resulting type distinction also yields new insight into the distinction between dynamic and stative predicates.

We motivate our use of the concept of force as the answer to the empirical problem of non-culmination. We note that previous attempts to account for non-culmination fall into two general categories: they either assume a causal relation between two subevents and require the additional machinery of possible worlds (e.g., Dowty, 1979), or they treat a non-culminated event as bearing some, possibly scalar, relation to a culminated event, but fail to adequately address the origin of

judgments underlying that relation (e.g., Parsons, 1989, 1990). We preserve insights from both of these previous approaches, proposing that there is a kind of causal relation, understood in force-dynamic terms, between two subarguments, but that something like scalarity (i.e., the fact that the endpoint need not be reached) is involved as well. We propose that non-culmination should not be understood as a derived phenomenon, but rather as the basic one: a dynamic verb refers to a force, rather than an event, and the existence of a force does not entail any necessary effect, because forces are naïvely understood to be inherently defeasible and to interact with each other in deterministic ways. To make the link between conceptual forces and semantic type theory, we map conceptual forces to Davidsonian arguments that are functions from an initial situation to a final situation that occurs *ceteris paribus*.

We demonstrate how this framework encodes the characteristics of familiar verb classes at the syntax-semantics interface, explicating the way in which the syntactic argument structure is interpreted to produce force-theoretic denotations which can express the insights achieved over the past two decades of research into the relationship between argument structure and event structure. We propose strictly compositional denotations for the substructures of change-of-state verbs, incremental theme verbs, manner verbs, resultatives, activity and semelfactive predicates. We argue that the force-theoretic approach can naturally distinguish between agent and causer arguments, and propose an analysis of source-introducing *from*-PPs.

Finally, the type-theoretic distinction between forces and situations takes center stage, as we examine the consequences of the proposed framework for dynamic predicates (predicates of forces) and stative predicates (predicates of situations) with respect to adverbial selection (as per Katz’s 2003 Stative Adverb Gap) and coercion. The framework allows as well for a natural account of predicates that have been resistant to analysis in event-theoretic approaches, namely verbs of maintaining like *keep* and *stay*.

1. Motivating forces

We begin with a difficulty encountered in the representation of Accomplishments in *ceteris non paribus* contexts where the telos is not reached. We argue that treating (certain) Davidsonian arguments as referring to forces addresses these issues in a more satisfactory way.

1.1 A *ceteris non paribus* problem with Accomplishments

A popular line of analysis investigating the internal structure of events has concluded that certain events—Vendlerian Accomplishments, most saliently—are composed of two sub-events, chained together in a causal relationship: *John opened the door*, for example, is argued to have a causing sub-event e_1 , and a result sub-event e_2 of the door being open. Such theories allow a straightforward expression of the insight that *John* is the Agent of only the first, causing, sub-event, e_1 ; this event then is ‘chained’ with e_2 , which is itself related to the Theme (Pustejovsky 1991, 1995), Higginbotham (2000), Folli 2003, Giorgi & Pianesi (2001), Kratzer (2005), Ramchand (2008), a.o.). The nature of this chain is typically either implicitly or explicitly assumed to be that of a causal relation of the form $\exists e_1 \exists e_2: e_1 \text{ CAUSE } e_2$, assuming Dowty’s 1979 (admittedly non-neo-Davidsonian) treatment of causation, itself derived from Lewis’s (1973) theory.

If indeed there is a causal relation of this kind in Accomplishments, a problem arises. For e_1 to cause e_2 in Lewis’s theory, both events must exist. This requirement is reflected in the existential binding

of e_1 and e_2 . However, there are many cases in natural language where e_1 appears to have this kind of causal relation to e_2 , at least *ceteris paribus*, but e_2 does not necessarily occur, because *ceteris non paribus*. We will discuss two such cases here.

The more well-studied of these cases is the so-called “imperfective paradox” in imperfectives and progressives (especially the English progressive; Dowty 1979, Parsons 1989, 1990, Landman 1992, Portner 1998 among many others). It is perfectly possible to say that Mary was painting the dresser without entailing that the result state occurred:

- (1) a. #Mary painted the dresser black, but she didn't finish.
- b. Mary was painting the dresser black, but she didn't finish.

Many theories of the progressive have addressed the contrast in (1). One category of theories involves quantification over a normal or “inertial” set of possible worlds or situations, so that e_1 causes e_2 , and e_2 indeed exists, but only in these worlds or situations; the actual world or situation need not be in this set. Dowty (1979) was the first to propose this solution, based on a suggestion from David Lewis. However, Dowty was well aware that inertia worlds represented a powerful complication of the model, and therefore adopted them only “reluctantly” (Dowty, 1979: 148). (See also Landman 1992, Bonomi 1997, Portner 1998, Naumann & Piñon 1997, Abusch 1985, Engelberg 2001, a.o. for possible worlds, Cipria & Roberts 2000, Del Prete 2012, for possible situations.) This move was a direct consequence of the problematic conjunction of two premises: (a) that Accomplishments have a causal relation, based on Lewis’s theory of causation, (b) that the causal relation, as defined by Lewis, requires that the result occur. The adoption of possible worlds does alleviate the problem. However, there are two different strategies that can be used to obviate the problem entirely.

The first strategy, call it “causal skepticism”, is to deny premise (a), namely, that there is a causal connection between an e_1 and an e_2 in Accomplishments. Essentially this position posits the existence of “partial events”: an event e can either hold without culminating (hence it is partial) or it can culminate (Vlach 1981, ter Meulen 1985, Bach 1986, Parsons 1989, 1990, Kearns 1991, Landman 1992,¹ Smith 1991, among many others). In these theories, a principle characterizing the intensional relation between partial and total events, where the total event is the normal or inertial continuation of the partial event, is assumed, or, in the case of Landman 1992, defined via possible worlds. Another way to define this principle is via a mapping to a scale along which an event is measured, from the least culminated to the most culminated (Bohnenmeyer & Swift 2006, Koenig & Chief 2007, Piñon 2008; see also Beavers 2011 on the ‘Affectedness Hierarchy’). A third way to think about the same principle is to map parts of events to thematic roles or objects (e.g., Krifka 1998, Filip 2008). A rather different approach to the causal skepticism strategy, represented by Asher (1992) and Glasbey (1996), is to take the progressive to apply to inferences that speakers and hearers make about utterances.² Such theories avoid the problem with Lewis’s theory of causation. However, they for the most part give up the straightforward association between agents and initiating events (Krifka 1998 and Filip 2008 excepted), and they all abdicate on the question of how to tell that one event is related to a more maximal or culminated event.

There is a second strategy for avoiding the problem introduced by the two premises above, which has not been utilized, as pointed out by Copley & Wolff, to appear.³ Namely, one could deny

¹ As Portner (1998) points out, Landman’s theory falls into this category even though it also uses possible worlds.

² This could still be understood as involving a kind of causal relation; see footnote 10 below.

³ Beavers (2011: 359 note 19), discussing non-result-entailing lexical items, also notes the existence of this type of strategy without making reference to theories of causation per se.

premise (b), that the existence of a causal relation entails that the result occurs. While many theories of causation, similarly to Lewis's 1973 counterfactual theory, propose a causal relation that is result-entailing,⁴ not all of them do. Copley & Wolff observe that "non-result-entailing" theories of causation exist: namely, probabilistic theories of causation (Reichenbach 1971, Suppes 1970, Eells 1991, e.g.), and force-dynamic theories of causation (e.g. Dowe 2000, Kistler 2006, Mumford & Anjum 2011). The latter is related to cognitive linguistic treatments of force-dynamics as constituting an important part of verb meaning (Talmy, 1976, 1988, 2000, e.g.; Croft 1990, 1991, 1998; Gärdenfors 2004, 2005, 2007); this line of inquiry seems to have developed independently from the philosophical debates on causation. See also Rappaport Hovav and Levin (2001) for a detailed application of the insights provided by a force-dynamic viewpoint to the problem of English resultatives.

In this article we pursue the force-dynamic version of this strategy. As far as the defeasibility of Accomplishments is concerned, our strategy is in a way causation-affirming, to the extent that force dynamics interprets the relation as supervening on physical causal mechanisms, rather than stopping at the level of observational correlations, as scales and probabilities do. However, it should also be palatable to causal skeptics, since force-dynamics describes more relations than just causation. (In fact, among causal skeptics the notion of "force recipient" is often appealed to, usually without formal development, though see Beavers, 2011.) In this paper we develop a syntax-semantics interface theory of Accomplishments based on a force-dynamic perspective, and extend it to the rest of event structure.

Although the problem posed by the English progressive has been the central case in the literature, it is important to note that empirical problems for the two premises above extend beyond the progressive. So-called 'non-culminating accomplishments'⁵ pose a very similar problem. In a number of languages, there are constructions in which telic predicates routinely fail to have a culmination entailment, so that the analogue of the sentence in (1a) above, for instance, is acceptable.⁶ Malagasy, for example, has an agentive infix, *-an-*, which according to Travis (2000) indicates the presence of an initiating event and an active Agent, but forms with the infix do not entail the result of the caused event—the occurrence of the result is implied, but defeasible, as described by Travis (2000), and illustrated in (2) below.⁷

(2)	namory	ny ankizy	ny mpampianatra		
	pst. <i>Agent</i> .meet	the children	the teachers		
	...nefa	tsy	nanana	fotoana	izy.
	...but	neg	pst.have	time	they.

⁴ Result-entailing theories include non-probabilistic causal modeling theories as in Pearl, 2000, Woodward, 2009; see also Hobbs 2005 for an application to language) as well as some theories based on energy transfer (Kistler, 2006).

⁵ We use the term 'accomplishment' following common usage in the literature, although this category includes some achievement predicates as well.

⁶ The failure to entail culmination might tempt one to wonder whether these cases are themselves some form of progressive or imperfective. Researchers have gone to some lengths to demonstrate that they are not. For the Salish cases, for example, Matthewson 2004 shows that these Salish forms do not behave in discourse as though they were derived statives. Bar-El et al. 2005 assert that the Salish neutral form is perfective, lacking an overt marking for imperfectivity. And in Dell's (1987) Tagalog example in (3), the neutral (non-culminating) form of the verb is marked as perfective in the initial clause; these verbs can also be marked for imperfective aspect, as he makes clear. It is therefore inappropriate to treat non-culminating accomplishments as containing, e.g., a null imperfective or progressive aspect.

⁷ In the data below that we have taken from previous articles, we adopt the author's abbreviations in each case. We will footnote those abbreviations that seem non-self-explanatory. In Dell's 1987 paper, "N" stands for the "neutral" form of the verb and "A" for the "abilitative" form of the verb.

"The teachers gathered the children but they didn't have time."
(Travis 2000: 173)

Similarly, the neutral form of the verb in Tagalog does not entail the result, but rather merely implicates it (Schachter & Otanes 1972, Dell 1987); the result can be explicitly contradicted.⁸

- (3) Inalis ko ang mantas, pero naubusan
N-pf-remove gen-I nom stain, but run-out-of
- ako kaagad ng sabon, kaya hindi ko naalis.
nom-I rapidly gen soap hence not gen-I A-pf-remove
'I tried to remove (lit. 'I removed') the stain, but I ran out of soap, and couldn't.'
(Dell 1987: 186)

In the Salish languages St'át'imcets and Skwxwú7mesh, according to Bar-el, Davis, and Matthewson (2005), the culmination of Accomplishments in otherwise unmarked forms is only implicated, not entailed.

- (4) a. k'ul'-ún'-lhkan ti ts'lá7-a,
make-TR-1SG.SU DET basket-DET
- t'u7 aoy t'u7 kw tsukw-s
but NEG just DET finish-3POSS
'I made the basket, but it didn't get finished.' (St'át'imcets)
- b. kw John na kw'el-nt-as ta skawts
DET John RL cook-TR-3ERG DET potato
- welh haw k-as 7i huy-nexw-as
CONJ NEG IRR-3CNJ PART finish-LC-3ERG
'John cooked a potato but never finished.' (Skwxwú7mesh)
(Bar-el, Davis, and Matthewson 2005: 90)

Examples can be multiplied further, but we will just provide one final one here. Karachay-Balkar, a Turkic language spoken in Russia, also has non-culminating accomplishments (Tatevosov 2008):

- (5) Kerim eşik-ni aç-xan-dı, alaj boşa-ma-~~an~~-dı.
Kerim door-ACC open-PFCT-3SG but finish-NEG-PFCT-3SG
(Context: The lock is broken, and Kerim tries to open the door.)
Lit. 'Kerim opened the door, but he did not succeed.'

⁸ Notice the different form of the verb *naalis*, 'A-pf-remove' in the continuation here; this form of the verb carries a completion entailment, i.e. an entailment that e2 occurs, here explicitly negated. In Malagasy there are also two such verb forms, one that entails completion and one that does not (see, e.g. Travis 2000: 172).

As should be clear from the disparate families represented by these languages, this is not an isolated phenomenon; indeed it may be the unmarked option crosslinguistically. See Singh (1998) for discussion of similar facts in Hindi, Giannakidou and Staraki (2010) for Greek, Koenig and Muansuwan (2000) for Thai, Koenig and Chief (2007) for Mandarin, and Paramasivam (1977) for Tamil.⁹

Just as in a progressive, in all of these non-culminating accomplishments the agent does something that normally leads to a result but can still be unsuccessful in getting the intended result to happen. Not surprisingly, analyses of these facts have appealed to the exactly the same technologies as analyses of the progressive. One group of theories exploits possible worlds for the rescue of a result-entailing theory of causation, e.g., Matthewson, (2004), Tatevosov, (2008). The other major group of theories deny that there is a causal relation, and instead relate partial events to culminated events, e.g., Koenig and Chief (2007), Singh (1998). Dell's (1987) description of Tagalog neutral verbs as denoting a "maneuver" to achieve a "result" is a significant outlier, being a non-result-entailing, force-dynamic strategy, and is very much along the lines of what we will propose.

1.2 Forces as functions: Interaction and intervention

The way that we propose to incorporate force dynamics into formal semantics is to understand forces as conceptual entities that are mapped to functions from situations to situations. We say a few words here about how we approach this, before developing the idea further below.

As we have seen, the fact that Lewis's theory is result-entailing is reflected in the existential binding of e_2 in the logical form. We have seen that e_2 should be introduced but its existence should not be asserted. We propose to accomplish this by treating the causal link as mapping to a function between an input and an output argument, where the latter is understood to be the unique result that obtains if all else is equal, proceeds normally, etc.; i.e., all the considerations that have gone into defining inertia worlds and the relation between partial and culminated events in the literature. The initial argument is bound existentially, as usual. The output argument, however, is defined as the output when the causal function is applied to the input argument. In this way, the output argument is defined, and thus can be referred to, without having to actually be asserted to occur.

We then might consider the input argument to be e_1 , and write in our denotations the following statement of the causal link between e_1 and e_2 :

$$(6) \quad f_{\text{CAUSAL}}(e_1) = e_2$$

This move could accommodate the cases of non-occurrence of e_2 that we address above within an event-chaining view. However, it should be noted that such an account would be successful only to the extent that f_{CAUSAL} could be defined at all over events. It is not trivial to ensure that there is a unique result e_2 of a given e_1 . Of course possible worlds could be recruited to define f_{CAUSAL} , but then we are back to the same problem as before.

Instead, we propose that the input and output arguments of a causal function are situations. The use of situations instead of events will provide for a unique output for any given input to the causal function, allowing the function to be properly defined. The input is an initial situation including all relevant causal conditions--the entities and their properties in the situation. If the causal function applies to a different s_0 , a different s_1 will result.¹⁰

⁹The last as cited in Koenig and Chief 2007.

¹⁰ In this our proposal will end up having a similar flavor to Asher's (1992) and Glasbey's (1996) theories of the

$$(7) \quad f_{\text{CAUSAL}}(s_0) = s_1$$

On this view of the causal relation, the causing event e_1 has disappeared from the calculus. What, then, is actually taking us from the initial to the final situation? Formally, it is the causal function that plays this role. The question here arises as to whether it is legitimate to interpret the causal function in some sense *as* the event.

There is a line of thought associated in large part with a tradition in computer science, that equates events with transitions between static representations of situations, as in motion pictures or comic books (Moens and Steedman 1988, Naumann 2001, Fernando 2004, 2005, ter Meulen 1990).

¹¹ Dahl (2007) also views events as transitions from one static situation to another.¹² For causal skeptics, there is no problem with interpreting events as defeasible; Moens and Steedman, 1988: 18-19), in fact, follow such a line in their account of the English progressive (asserting the superiority of such a theory to a possible worlds account). However, we think that such a move—mapping the causal function to the conceptual event—is missing an important fact about the world: there is already a fundamental concept in the relevant domain that is itself not result-entailing when *ceteris non paribus*, namely *force*, which can be thought of as a directed input of energy that may or may not provoke an effect, depending on the circumstances.

The key advantage of force and energy talk over event talk lies precisely in the ability of forces to interact with each other. It is natural to think of a force summing with another force to create a larger impetus to an end; similarly, it is natural to think of defeasibility as stemming from a case where a force counteracts another force that, without that intervention, would have led to some particular end. In contrast, it is not clear how one event might perturb or sum with another, especially if an event corresponds formally to the adjustment of a value on a scale.¹³ What is missing from event-talk is a clear notion of just how something external to the event can intervene to change the adjustment of the value along the scale; we certainly don't have a model of how values on various scales might interact with each other. An event-theorist might object that they are not in the business of modeling such interactions, which is fine, but we will argue that this ability to model interaction allows for a perspicuous approach to several thorny empirical problems.¹⁴

progressive. Asher characterizes a 'perspective' as a "subset of information about a state." For Asher, the inference from $\text{Prog}(\phi)$ to ϕ is defeasibly valid; it can, in particular, be defeated by the inclusion of additional information from the speaker's perspective. The difference between these theories and ours is that while theirs deal with information states, ours deals with states of affairs in the world. Inferences are the analogue of forces. It also assumes determinism if the speaker has perfect knowledge.

¹¹ Davidson (1967) expresses skepticism that events can be represented by transitions from one state to another, remarking that there are any number of ways to go from San Francisco to Pittsburgh (by foot, by air, by mule, ...) and all these are different kinds of events although the initial and final state are the same. This objection does not, however, pertain to the idea of events as functions from one state (situation) to another. There are any number of ways to get from the integer 2 to the integer 4 ($x+2$, $x*2$, x^2 , ...) by way of distinct functions; likewise, there are in general different ways to get from one situation to another by way of distinct functions.

¹² In a related vein (also to the preceding footnote), the analytic tradition that includes Discourse Representation Theory and Dynamic Semantics (Kamp 1981, Heim 1982, Groenendijk, J. and M. Stokhof 1991, Kamp and Reyle 1993, Beaver 2001, etc.) also formally implements causal transitions, in this case between information states rather than situations.

¹³ Neither is it altogether clear in what sense two events might help, oppose, prevent, or maintain one another.

¹⁴ It is interesting to note that facts (information, inferences) can interact in a defeasible fashion as well (Asher, 1992, and see footnote 10 above). However, if we work only with facts, we give up the advantages of Davidsonian

This ability of forces to model intervention is especially appropriate in the analysis of a long-standing puzzle in the event-structure literature concerning the status of verbs of maintaining like *keep* and *stay* (Jackendoff 1975, a.o). They are clearly dynamic, as diagnosed by the usual eventuality tests; for example, the progressive gets an 'ongoing-now' reading.

- (8) a. The rock is keeping the door open.
- b. The door is staying open.

Their occurrence in the progressive shows that these verbs *can* be dynamic. However, the fact that they are interpreted habitually in sentences such as those in (9) with the simple present indicates that they *must* be dynamic:¹⁵

- (9) a. The rock keeps the door open.
- b. The door stays open.

In an event-based framework, it is difficult to understand what distinguishes such dynamic eventualities from stage-level statives such as *The door is open*. In standard neo-Davidsonian approaches, both kinds of predicates take a Davidsonian argument, and both make reference to a situation in which the *The door (is) open* holds, so there is no obvious formal rationale for their distinct aktionsart types. Further, in a semantics in which the Davidsonian argument is an event and events are characterized by change (i.e., along a scale; see Cleland 1991: 245 for a philosophical perspective on how to characterize events), it is difficult to understand the notion of a “eventive” eventuality like *keep* or *stay* in which nothing changes.

In contrast, the discussion of such verbs in the cognitive linguistics literature (Talmy, 2000, e.g.) points out that the key difference between *The door was open* and *The door stayed open* has to do with the fact that the latter lexically encodes the presence of a force that intervenes to counteract the *ceteris paribus* result of an existing force; without the staying force, the door would not have remained open. The dynamic character of these predicates, we argue, reflects the fact that they involve a force, not that they involve an event or change of any kind.

To capture the notion of intervention that will allow us to account for cases of perturbation and maintenance, we will map conceptual forces to functions that have the form of the causal function we described above in (7). Intervention is easily modeled using functions: two functions can be summed to yield a different result that one would get just from one of the two functions.¹⁶

modification. We think forces are a good compromise between the Davidsonian evidence that make us want to anchor our ontological entity in the physical world (i.e., what events are good at), and the ability of these entities to interact with each other, even to construct different possibilities that proceed from a present situation selected by the speaker (i.e., what facts are good at; and see Kratzer, 2013, e.g. for an indication that mainstream modal theory is moving in that direction).

¹⁵ They are also compatible with *for an hour* but not *in an hour* adverbials. This constellation of behavior (compatibility with progressive, habitual interpretation in present tense, and atelicity) shows them to fall squarely into the Vendlerian class of activity predicates, as far as their Aktionsart properties go. (Note that stative predicates, which are also atelic, are incompatible with the progressive and allow a true present tense; these predicates are not stative.) They are atypical activity predicates, however, in clearly being causative.

¹⁶ Note that our formal force function differs from the conceptual forces detailed in Croft, 1990, 1991 and other cognitive linguistic approaches, in that force functions act on entire situations rather than acting on a particular object (the 'force recipient').

The ability to interact is just one of the properties that make the notion of force suitable for addressing the empirical challenges we lay out above. Additionally, forces are intuitively spatially and temporally located, in that they arise from objects and their properties, which are themselves the components of spatially- and temporally-locatable situations. Lastly, forces can transform objects and/or their properties—that is, they create new situations from old situations. For any given situation, we can sum the forces acting in it to arrive at a *net force*, whose *ceteris paribus* effect will be to lead to the subsequent situation. ‘*Ceteris paribus*’ now means exactly that no outside forces intervene, where ‘outside forces’ are those that arise at least partially from entities outside the situation under consideration.

2. A selective tour of theories involving forces

In this section we take a very brief tour of some relevant existing work. We note that many researchers working on verbal semantics have turned to concepts such as ‘force’ and ‘energy’ even when they have not explicitly used these intuitions in their theories, or, when they have, have not provided a formal interpretation of them. Psychologists investigating intuitions about causation have developed a consensus that causal reasoning is driven by the perception of physical causal mechanisms connecting entities; this finding implicates forces. Finally, we address the state of the art within formal linguistics, especially the only existing formal framework we know of to use the notion of forces (van Lambalgen & Hamm 2003, 2005), and detail how our approach relates to it. This review serves to situate our proposal, developed in the following sections, that the causal function itself maps to a conceptual force in the mental representation of the world, and ultimately, that the causal function takes the place of the event argument for dynamic eventualities.

2.1 Generalizing forces for verbal meanings

One might wonder whether the notion of ‘force’ be generalized or abstracted in a useful way to all dynamic verbal meanings. We draw an analogy to a more familiar (at least to formal linguists) abstraction, one that abstracts away from physical motion to abstract motion, i.e., other kinds of change. This kind of abstraction is already present in Aristotle’s *Physics* (V.2):¹⁷

...there can be motion .. in respect of Quality, Quantity, and Place... Motion in respect of Quality let us call alteration.... Motion in respect of Quantity ... is called increase or decrease.... Motion in respect of Place ... we may designate ... by the general name of locomotion....

As we have noted above, this insight has been incorporated into modern event semantics via the concept of a scale.¹⁸ However, like physical motion, physical forces can be abstracted in the same way. Indeed, the prototypical cases of physical forces are those that may (or may not) produce motion

¹⁷ Aristotle does not extend this analysis to verbs of creation and destruction (V:1): “those which take the form of ‘becoming’ and ‘perishing’, that is to say those which imply a relation of contradiction, are not motions...” We assume, however, that it applies to all predicates; see our treatment of incremental theme verbs in section 4.2 below.

¹⁸ This generalization to change along a scale is pervasive in the lexical semantic, cognitive linguistic and formal literatures on events (see, among very many others, Levin & Rappaport Hovav 2008, Jackendoff 1975, 1991, Talmy 2000, Croft 1991, Ramchand 1997, 2008, Hay, Kennedy & Levin 1999, Kennedy and McNally 2005, Kennedy and Levin 2008, etc.)

of an object: think billiard balls. It seems reasonable, therefore, for a model of physical forces to be generalized to other domains in a similar sense: representing inputs of energy that may or may not cause changes of an abstract kind.

In the cognitive linguistic tradition, forces have been generalized in this way to form the core of all dynamic verbal meanings. Talmy (1976, 1981, 1985a, b, 1988, 2000) was the first to propose that the notion of force is relevant in linguistic semantics, starting from the common-sense insight that the meanings of certain verbs (e.g., *keep*, *help*, *prevent*, etc.) are easily characterized in terms of force-dynamic interactions. Talmy's insight has been explored and developed at length by others. Croft (1990, 1991, 1998, e.g.) follows Talmy in treating active verbal predicates as denoting force-dynamic relations, and in understanding causation through this lens. In a prototypical causal scenario, for example, "one participant acts on another participant and transmits its force to the other participant, which then undergoes a change" (Croft 1998:83). Gärdenfors (2007) similarly extends the Talmian project to characterize verbal concepts as patterns of forces:

Even though our cognition may not be built precisely for Newtonian mechanics, it appears that our brains have evolved the capacity for extracting the forces that lie behind different kinds of movements and action.... In accordance with this, I submit that *the fundamental cognitive representation of an action consists of the pattern of forces that generates it*. (Gärdenfors, 2007: 254)

The idea of a force is also represented in the formal literature as an intuition even where it has not been developed in a formal sense. Consider the following characterizations of intervention: "[W]e assume in reasoning ... that...other outside forces don't intervene." (Asher, 1992: 491); "Landman points out that sometimes the forces out to stop an event are just too strong to allow a progressive sentence to be true." (Portner, 1998: 766)¹⁹ And of event structure: "The causal chain represented in an event structure is essentially a representation of the event as a series of force-dynamic relations." (Rappoport-Hovav & Levin 2001: 787).

Similarly, the idea of energy, closely related to the idea of force, has long been understood to be fundamental to the relationship between states, events, and to transitions from one to another:²⁰

"With a state, unless something happens to change that state, then the state will continue.... With a dynamic situation, on the other hand, the situation will only continue if it is continually subject to a new input of energy. [...] To remain in a state requires no effort, whereas to remain in a dynamic situation does require effort, whether from inside or outside ." (Comrie 1976: 49)

"Events and states also differ in *energeia*, or dynamism. Events require energy... [s]tates consist of an undifferentiated period, and continue unless something happens to change them." (Smith 1997: 36)

¹⁹ Landman does not in fact use the word "force" in his 1992 article.

²⁰ In related discussion, Bohnemeyer and Swift (2006) recognize the importance of force in the semantics of the English progressive for certain predicates, though they characterize 'change' rather than energy or force as the defining property of dynamic predicates. Many others have also described dynamic predicates as crucially involving 'change', including Dowty 1979, Kearns 1991, and McClure 1994. We address the question of whether dynamic predicates always entail change in section 5.3 below, in our discussion of verbs of maintaining.

The notions of force and energy, then, have been repeatedly implicated in the study of verbal meaning.

We turn now to psychological research on causation, which also suggests that the use of forces to account for verbal meaning is cognitively plausible. This suggestion stems from findings demonstrating the primacy of forces in causal reasoning, including when causal interactions are described linguistically using verbal predicates.

2.2 Research on causation implicates physical causal connections

There is a consensus in the psychological literature on causation that, as cognitive linguists would predict, people's representations of physical reality do include information about causation physically anchored in space and time, over and above basic spatio-temporal properties such as motion. Michotte (1946/1963) hypothesized the existence of a dedicated causal perception mechanism, based on the results of experiments manipulating the temporal and spatial distance between interacting objects in animated sequences. Subsequent work building on his results confirm the primacy of causal perception, in adults and also in infants. For example, Leslie and Keeble (1987), using a preferential looking paradigm, showed that infants as young as six months old perceive causation. Subjects were shown a sequence where a hand is moving together with an object, in two conditions, either where the hand contacts the object or where the hand does not contact the object. When the sequence was run backwards, the infants were habituated in the non-contact condition, but looked more in the contact condition. This suggests that the infants interpreted (only) the contact condition as a causal event, which would seem quite different if run backwards in time.²¹ Walsh & Sloman (2011) present experimental evidence that adults tend to attribute causation only when there is the possibility of a physical causal mechanism between two events; in the absence of such a possibility, causation is attributed much less, even when there is a correlation between the two events. This result strongly suggests that in people's mental representation of a scene, they have access to the notion of a physical causal mechanism. Indeed, work by Wolff and others (Wolff & Song, 2003, Wolff 2007, Barbey and Wolff 2007, Wolff, Barbey, & Hausknecht, 2010, Wolff, Hausknecht, & Holmes, 2011, Wolff, to appear) has extensively argued for the psychological validity of these proposals using experimental methods.²² These experiments show that the magnitudes and interaction of physical forces in a virtual environment can be very precisely predictive of speakers' choice of lexical items for causal predicates, and that the effects transfer unproblematically to psychosocial contexts.

Force dynamics allow us to model causal information as physically anchored in space and time. In fact, to the extent that causal information is always thusly anchored, force dynamics may be the best way to model causal information, since spatio-temporal information is crucial to forces, but not to other theories of causation. Copley & Wolff (to appear) argue that the fact that spatio-temporal information is relevant to causal attribution indicates that a production/mechanistic theory such as force dynamics should be used to explain the mental representation of causation, since other theories (counterfactual, probabilistic, e.g.) do not make reference to space or time at all and therefore have to stipulate any

²¹ See also Saxe & Carey (2006) for an overview of research on infants' representations of causation. This research tends to elaborate on the kind of causal knowledge that infants have, rather than objecting to the idea that infants have causal knowledge.

²² The representation of force as a vector towards the endstate or result, as in Wolff's model, is well-suited to talking about cases of intervention, where the endstate occurs only defeasibly.

relationship between causation and spatio-temporal information.

Although the relevance of forces for models of causation is coming to be recognized in the psychological literature, investigation of the relationship between cognizing about forces and cognizing about causation is ongoing. White (2011), for instance, concludes that forces and causation are independent of each other, based on experimental results showing that subjects' impression of force magnitude in animated sequences is influenced by the size of a gap between two interacting objects, as well as by the presence of an intervening third object, but their impression of causation is not.²³

2.3 Forces in formal linguistics

Despite the ubiquity of the concept of 'force' in cognitive linguistics, and its usefulness in psychological investigations of causation, as far as we know, there have not been many formal linguists who have explicitly deployed the concept of force in the analysis of natural language phenomena. Those who have, have not gotten as far as providing a formal interpretation (we have in mind Vecchiato 2003, 2004 and Zwarts 2010).

The only formal semantic framework to systematically employ the concept of 'force' that we are aware of is work by van Lambalgen and Hamm (2003, 2005). The latter authors share several convictions with the present approach. One such shared conviction is that the concept of *ceteris paribus*—their notion of 'inertia'—is central to the treatment of verbal predicates, is ultimately derived from representations of causation, and should be treated directly in the model: possibilities are derived from causation, instead of the other way around as Lewis (1973) proposes. Another shared idea between the present approach and van Lambalgen and Hamm is that there is a kind of local determinism such that there is always a single “next thing” that happens:

“We interpret fluents as sets of intervals of the form $[0, b]$ or $(a, b]$, where a is the instant at which an initiating event occurs, and b is the instant where ‘the next’ terminating event occurs. Talk about ‘the next’ seems justified due to the inertia inherent in fluents.” (van Lambalgen and Hamm 2005: 47)

This same assumption underlies our contention (above) that it is appropriate to represent causation as a function, with a unique output.

However, it is important to note some differences between our proposal and van Lambalgen and Hamm’s as well. One basic ontological distinction in van Lambalgen and Hamm’s model is a temporal distinction, between instantaneous *events* and time-dependent (non-instantaneous) *fluents*. A

²³ There are two reasons why White’s results do not derail the current project. One is that it is perfectly possible for there to be forces acting without the source of those forces being a subject of the main verb *cause* (used in White’s instructions to subjects). The second is that, following ongoing debate in the philosophy of causation, we are happy to remain agnostic on the question of whether a single theory of causation can account for *all* causal impressions (Anscombe, 1971; Hall, 2004; Copley & Wolff, in press, and especially Godfrey-Smith, 2009 for a fine overview of the topic). Copley & Wolff, in press, suggest that spatio-temporal anchoring may be most relevant in the verb phrase, but less relevant outside it. In this paper we remain inside for the most part the verb phrase, but leave open the possibility that other notions of causation operate outside of it.

fluent can either be a state such as “have momentum m ” or a force that continuously causes another fluent. This ontological choice to group states and continuous forces together would run into empirical problems with the adverbial data from Katz that we discuss below in section 5.1, since it does not make a type-theoretic distinction between states and events. Thus we do not adopt van Lambalgen and Hamm’s model.²⁴

We should also point out that, in contrast to both the cognitive tradition²⁵ and van Lambalgen and Hamm’s work, we seek to elucidate how the representation of force in the semantics interfaces with the syntax, taking into account recent models of the syntax-semantics interface. With a view towards this goal, we implement the notion of force in the next section.

3. A scaffolding for a force-theoretic semantics

Overall, despite the longstanding interest in, and inherent plausibility of, the idea of force, the difficulty of expressing force in current model-theoretic approaches has inhibited further development of this idea at the syntax-semantics interface. More than one researcher has expressed their interest, however, in a formalized theory of forces that would integrate naturally with what we have learned about the syntax-semantics interface (see, e.g., Dowty, 1991: 575, Rappaport Hovav & Levin 2001:785 n. 21, Beavers 2011: 357). We provide a sketch of such a theory here; for a full model-theoretic treatment, and more detailed discussion of the philosophical and conceptual underpinnings, see Copley & Harley, in preparation. For the brief presentation here, we will concentrate on force functions and situations, but a few words must be said first about the mapping between conceptual forces and (conceptual) situations on the one hand, and force functions and situations on the other.

3.1 Forces and situations

A conceptual force—a force as it is perceived and mentally represented—arises from the individuals and properties that comprise an initial situation.²⁶ We assume that the cognitive system sums the forces acting in a conceptual situation to calculate the trajectory or development of that situation. Zacks et al. (2011) show, by observing behavior and brain activity during near-future prediction tasks, that prediction of the development of a situation is psychologically real and is sensitive to transitions. Our proposal is that this kind of prediction is accomplished via a force summation, which for purely spatiotemporal forces is similar to that in a free-body diagram.²⁷ The product of the summation is a

²⁴ A more conceptual point is that while van Lambalgen and Hamm are of the opinion that it does make sense to talk about events “intervening” to change properties, we feel, as we have said above, that in the absence of a mechanism which can explain how an event (understood as a ‘change’) can itself initiate ‘change’, event-talk does not further our understanding of intervention in the same way that forces can.

²⁵ Another difference between the present project and the works cited above in the cognitive linguistic tradition is that the latter is concerned to a large extent with what we might call lexical force interactions (as in *help*, *prevent*), in which a single lexical item evokes a particular pattern of force interactions, while we are primarily focused on how the concept of force (in particular, *net* force, see section 3 below) maps to functional material. This is not to say that the lexical force interactions do not interest us (see, for instance our treatment of verbs of maintaining in section 5.3 below) but rather that we seek to understand first how force-dynamically basic verb meanings are composed.

²⁶ On the other hand, not all functions from situations to situations characterize forces.

²⁷ The cognitive apparatus’s force summation calculation for a situation is thus massively multidimensional,

force which produces the single situation that happens next. We will call this the 'net force' of the initial conceptual situation. The estimated outcome of the predicted trajectory is itself a situation, which may or may not differ from the initial situation; this is the mapping from situations to situations that corresponds to our formal treatment of force as a function.²⁸

These conceptual forces, in particular conceptual net forces, are mapped to force functions: functions from an initial situation to the situation that occurs if nothing external intervenes, i.e. the situation that occurs *ceteris paribus*. We can summarize our conception of situations and forces as in (10) and (11) below

(10) *(Linguistic) situations:*

A (linguistic) situation *s* corresponds to a conceptual situation, which is a spatiotemporally bounded “annotated snapshot” of individuals and their properties.

(11) *(Linguistic) force functions:*

A (linguistic) force function is a function from an initial (linguistic) situation to the (*ceteris paribus*, linguistic) final situation, which corresponds to a conceptual force. The latter is an input of energy that arises from individuals and their properties in a conceptual situation.

To represent situations in a Montagovian semantics (Montague 1970), we assign them the primitive type *s*.

(12) *Type of situations: s.*

Type of forces: <s, s>

As we have said above, we propose to represent forces as functions from situations to situations. The idea behind the <*s,s*> type is again the assumption that we share with van Lambalgen and Hamm, that there is such a thing as the next situation. That is, if you have an initial situation and a force is applied, and no stronger force intervenes, the final situation results—not a different *set* of situations but a single situation. For convenience we will abbreviate type <*s,s*> as type *f*.

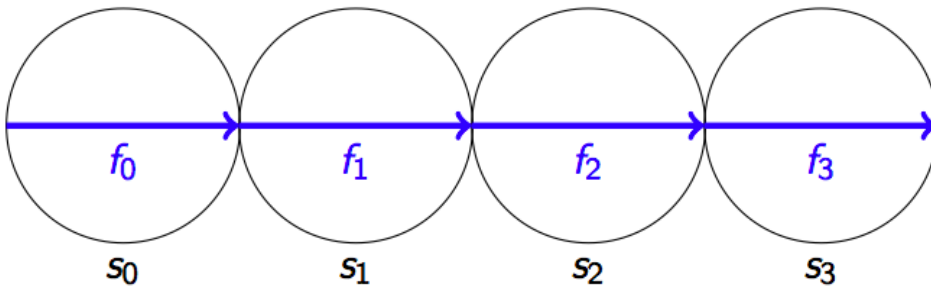
Because conceptual forces arise from individuals and their properties in conceptual situations, we can relate forces to situations, not only on the conceptual level, but on the linguistic level as well.

including forces acting in directions other than the purely spatial. In our model, forces (inputs of energy) are what produce change. As noted above, we therefore conclude that forces are appropriate to model predicates denoting any type of change, not only change of location. Thus forces can arise that produce any of the kinds of changes that Aristotle alludes to: a 'grow' force (an input of energy that *ceteris paribus* provokes an increase in size), a 'redden' force (an input of energy that *ceteris paribus* provokes a change in color qualia), a 'straighten' force (an input of energy that *ceteris paribus* provokes a change in linear configuration), etc. In this way, we generalize from forces with purely spatiotemporal effects to those with all kinds of other effects.

²⁸ Note that some forces are produced not by the behavior or motion of particular entities or objects, but are the result of the application of natural laws and generalizations, for example, the interaction of objects with mass and a gravitational field. We term the collected set of such laws and generalizations the 'normal field'. The normal field is the propensity of certain individuals and properties to generate energy in particular circumstances unless prevented from doing so. An object with mass in a normal gravitational field will have weight and fall unless prevented from doing so; similarly, an object (e.g. foodstuffs) with organic material in a normal temperate climate will have rotting potential and degrade, unless prevented from doing so, etc.

When a force arises from all the individuals and properties in a situation, it is the *net force* of the situation. The net force, as discussed above, yields a unique output situation. Since we assume local determinism, we may speak of causal chains of situations or forces, with the net force of one situation, when applied to that situation, resulting in a unique successor situation. This means we can also assume that a precedence relation $<$ and a subsequence relation $>$, both relating situations in such a chain, can be defined. The diagram below depicts a causal chain made up of situations (the vectors are depicted *in* the bubbles because the forces arise from the situations represented by the bubbles).

(13) Causal chain of situations with net forces



We assume that for a given linguistic situation s_n , we can always recover its net force f_n .

(14) $\text{net}(s) =$: the net force of s

By means of the inverse of the function *net*, net^{-1} , we can define two other functions that will be useful when we refer to forces and situations in denotations, as we will see below in sections 4 and 5. Given a (particular, spatiotemporally bounded) force f , we can refer to both the situation of which it is a net force, and the situation that follows. The initial situation of f is simply the situation s of which it is a net force. The final situation is the situation that results when f takes s as its argument.²⁹ The functions *init* and *fin* are defined with respect to the inverse function of *net*.³⁰

- (15) a. $\text{init}(f) = \text{net}^{-1}(f)$
b. $\text{fin}(f) = f(\text{net}^{-1}(f))$

We define as well a situation's successor and predecessor situation:

- (16) a. $\text{suc}(s) = \text{fin}(\text{net}(s))$
b. $\text{pred}(s) = \text{suc}^{-1}(s)$

²⁹ As noted by a reviewer, the job done by $\text{fin}(f)$ could equally be described in terms of the *init* function, as $\text{fin}(f_0) = \text{init}(f_1)$; we could thus define a single function that takes forces and returns situations, instead of two such functions as in (23). However, we retain the distinct names for their intuitive ease when relating with the initial and final situations of a force to a lexical entry; cf. the 'beg(e)' and 'end(e)' functions in Kennedy (in press).

³⁰ For any function F whose domain is over x and range is over y , a function G is the inverse function of (written F^{-1}) iff for all x , $G(F(x)) = x$, or equivalently, $F(x) = y$ and $G(y) = x$.

As usual, individuals will be represented by variables x, y, z, \dots and will have type e . Predicates are represented by lowercase Roman letters p, q, \dots . When they are (stage-level) statives, they are predicates of situations, type $\langle s, t \rangle$, and when they are dynamic, they are predicates of forces, type $\langle f, t \rangle$.

When an individual's property has a leading role in generating a conceptual force, we will say that the individual is the *source* of the corresponding linguistic force. We discuss the notion of 'source' in further detail in section 4.5 below, although without coming to an exhaustive definition of "leading role". In any case, the 'source' relation will serve the same purpose in our denotations as 'agent' or 'causer' serves in event-based frameworks.

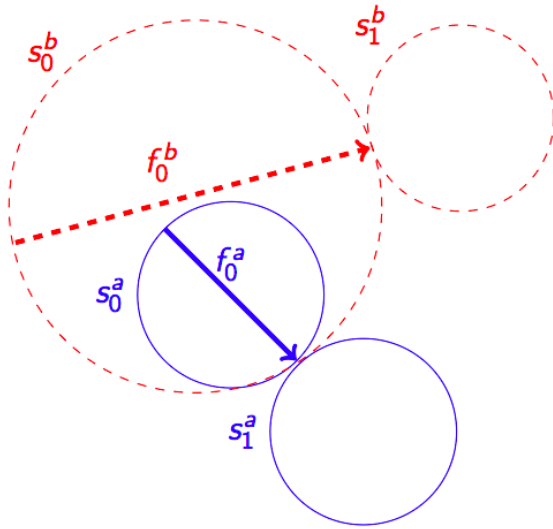
3.2 Efficacy and the *ceteris non paribus* cases

We argued above that the notion of intervention seems to be key to understanding the *ceteris non paribus* cases. Built into this notion is a distinction between internal (or judged relevant) circumstances and external (or unexpectedly relevant) circumstances; an intervention is an interaction where a force arising at least partially from external entities and/or properties interacts with internal forces. This distinction can be modeled quite easily by exploiting the speaker's judgment as to which entities and properties go into the initial situation. Not incidentally, the categorization of entities and properties as internal or external to the initial situation will also be crucial to reconciling our assumption of local determinism with branching possibilities.

We begin with a definition: a situation s_0 is *efficacious* just in case its *ceteris paribus* successor situation occurs. When choosing an initial situation s_0 , the speaker chooses (the) one that she judges to be efficacious. For example, she may judge that s_0^a is the efficacious situation; in that case, given her conception of the contents of that situation, she is judging that no forces arising at least partially from outside s_0^a will perturb f_0^a , so that s_1^a will indeed occur. Of course, something from outside s_0^a may well intervene, in which case perhaps the efficacious initial situation is s_0^b and what will occur is *its* successor s_1^b .³¹ So while there is local determinism, what eventually happens is not determined by the situation the speaker picks.

³¹ As an aside, we note that the scenario sketched above exemplifies how the force-theoretic framework deals with branching time; the superscripts a and b correspond to "branches" as in Thomason 1970.

(17)



The notion of efficacy will allow us to further understand our *ceteris non paribus* cases, that is, the non-culminating accomplishments and the English progressive.

We propose that the difference between forms that entail culmination of accomplishments (that is, entail that s_1 comes about, as in an English perfective) and forms that do not (like the Tagalog neutral form) is that the former presuppose that the initial situation is efficacious, while the latter have no such presupposition.³² As we mentioned above, this makes the non-culminating forms illustrated in (2-5) above more basic than the forms that entail culmination, contra inertia world treatments of non-culminating accomplishments such as Koenig and Muansuwan, 2001, Matthewson, 2004, and Tatevosov, 2008, and this is consistent with their comparatively unmarked morphological structure.

The meaning of the English progressive in (1) is different from that of non-culminating accomplishments, as we have seen above. We assume that Aspect maps from predicates of forces to predicates of situations, so it is type $\langle\langle f, t \rangle, \langle s, t \rangle\rangle$ (this assumption is analogous to the common assumption that aspect maps from event predicates to temporal predicates; Klein 1994, Kratzer 1998). As a first proposal, we suggest a denotation for the progressive that takes a predicate of forces (π , the denotation of the νP), and a situation (s_0 , the situation provided by tense), and says that the property π holds of the net force of s_0 ; efficacy is presupposed.³³

(18) $[[\text{progressive}]] = \lambda\pi \lambda s . \pi(\text{net}(s))$
 presupposition: s is efficacious

³² In fact, we have proposed elsewhere that there are forms which presuppose that the initial situation is *not* efficacious: a 'frustratives' in Tohono O'odham (Copley & Harley, in press). Futures and futurates also seem to have a presupposition related to the success of the eventuality (Copley, 2002, 2008). In the cases at hand, not all of the presupposition tests give clear results to decide whether efficacy is part of the assertion or a presupposition. However, in these other cases the analogue of efficacy (or non-efficacy, in the case of frustratives) is more clearly a presupposition, in that it survives questioning, negation, etc. So on balance, we think that also in the cases discussed here, efficacy is probably a presupposition.

³³ We assume that this presupposition is projected from the little ν below the progressive, and is not part of the meaning of the progressive itself.

So, for example, if John is baking a cake, the net force of the current situation is one which leads to a situation in which a cake has been baked by John, if all else is equal. The essence of the imperfective paradox is that all else may not be equal in the progressive—that is, the telos may not be reached. This principle may seem at first glance to contrast unfavorably with the proposed efficacy presupposition. But consider the contrast in (26) below:

- (19) a. John was baking a cake, but he didn't finish.
 b. ?John is baking a cake, but he won't finish.

As far as (19a) is concerned, it seems at first glance that the current situation referred to in the first clause of (19a) is *not* efficacious. There is no presupposition that John finished the cake; if there were, the continuation in (19a) would be infelicitous. On the other hand, (19b) is somewhat infelicitous (the only reading involves taking John's perspective). The difference between (19a) and (19b) is that in (19a) the initial situation of the first clause and the initial situation of the second clause can be different. In particular, the situation for the first clause is the s_0 in which John was messing around in the kitchen. Included in this situation is John, the kitchen, John's properties, and so on—and nothing else. However, something abnormal intervenes --- John gets bored, or the cake unexpectedly catches on fire, and so it turns out exceptionally that s is not efficacious. Instead, a larger situation s'_0 determines, in the end, what happens; its successor s'_1 comes to pass, not the successor of s_0 (i.e., s_1 ; see the diagram in Fig.1). This interpretation is apparently unavailable for (19b) because s_0 in both clauses has to be the same situation, i.e. the topic situation provided by present tense. So in both clauses in (19b) the speaker has to pick the *present* situation that they *currently* think is efficacious, and it is, we propose, odd to change one's mind mid-sentence about which situation s at the present time is efficacious. However, the acceptability of (19a) shows that one *can* change one's mind mid-sentence when talking about different past situations; in other words, the judgment of the efficacy of the past situation is, for past progressives, required to have been a *past* judgment, which might not have proved correct. We conclude that the English progressive does in fact have an efficacy presupposition but that in the past tense, the possibility to change the initial situation presupposed efficacious to a different one can make it look as though it does not.

This concludes our brief sketch of what a force-theoretic semantic model should, at minimum, include. In the remainder of the paper we will investigate how this force-theoretic semantics can be implemented at the syntax-semantics interface, given a specific set of assumptions about the structure of the relevant syntactic representations. The logical forms (i.e., meanings) we propose could easily be recast in an alternative representation of lexical-semantic structure, even if one does not wish to make the specific assumptions we make about the syntax (or indeed any assumptions at all about the syntax). However, we feel strongly that the use of syntactic evidence to constrain and inform theories of meaning enhances the relevance of both semantic and syntactic theorizing.

We will first consider how force-theoretic meanings integrate with syntactic argument structure, and subsequently, in section 5, we will show how this integration accounts for distinctions between dynamic and stative predicates.

4. Argument structure and event structure

We now turn to the integration of the force-theoretic framework with one current understanding of verbal argument and event structure, focusing on the representation of different eventuality types and their argument-structural properties. We will first consider how the various subclasses of dynamic predicates are composed, beginning with changes of state. Recall that we have proposed that the foundational distinction between stative and dynamic predicates is that stative predicates are predicates of situations, type $\langle s, t \rangle$, while dynamic predicates are predicates of forces, type $\langle f, t \rangle$.

4.1 Changes of state

The recent explosion of work on the argument structure/event structure interface has resulted in the development of a broadly accepted syntactic decomposition of the VP, into two or more phrasal projections, the maximal one typically labelled 'vP'. We adopt several core assumptions of the general approach in our proposal below, mostly those which have to do with the view that the internal structure of vP correlates robustly with the internal structure of events. However, any analysis which approaches subeventual structure in terms of hierarchically structured lexical-conceptual representations will easily be able to interpret our proposed recasting of the key components in force-theoretic terms. For change-of-state predicates in particular, we assume that each of the various subpredicates involved project independently in the syntax, and compose to generate the vP's denotation (Van Valin 1990, Hale & Keyser 1993, Borer 1998, 2005, Kratzer 1996, Ramchand 2008, among many others). For the most part, the syntactic literature treats change-of-state predicates like *melt* as having (at least) two components: a causing event and a result state (though cf. Piñon 1997 and Marin and McNally 2011, where it is argued that some inchoative predicates are truly instantaneous). In the current proposal, the causing event corresponds to a force which is applied to a situation of which the resulting stative predicate does not hold; this force (*ceteris paribus*) yields a situation where the resulting stative predicate does hold, following Dowty (1979).³⁴

Since each subcomponent of a change-of-state predicate is introduced in a separate syntactic projection, a change-of-state-denoting vP minimally contains two phrasal projections.³⁵ The lower portion of such a complex vP is taken to denote the resulting stative predicate. We assume it has the syntax of a small clause (SC) (see, among others, Hoekstra and Mulder 1990, Harley 2005, Ramchand 2008), which denotes a predicate p of situations (type $\langle s, t \rangle$). The head of the upper portion of the complex vP, v° , thus takes a predicate of situations p as its argument and ensures that the vP node denotes a predicate of forces (type $\langle f, t \rangle$). The v° head introduces a force f and asserts that p holds of the final situation of that force—that is, it identifies $\text{fin}(f)$ as a p situation. The v° head of a change of state predicate further imposes the requirement that that the initial situation of the force is a $\sim p$ situation.³⁶ (Recall that by the definition in (15a) $\text{init}(f)=s$ if and only if $\text{net}(s)=f$, so the initial situation of f is the

³⁴ Note that this is a generalized motion vector, in Aristotle's sense, as it represents a change from a not- p situation to a p -situation.

³⁵ One perspective on the historical development of theories about the syntax/event-structure relationship can be found in Rosen (1997) as well as in many of the references cited above.

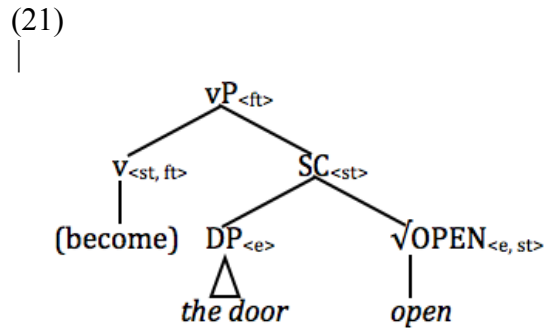
³⁶ We are here abstracting away from the fact that most such small clauses are headed by scalar predicates which denote relations between degrees, individuals and situations; see Hay, Kennedy & Levin (1999), Kennedy & McNally (2005), Kennedy & Levin (2008), Levin & Rappaport Hovav (2010), a.o. Nothing relevant to the discussion here hinges on the adaptations necessary to fully represent the scalarity of the embedded predicate; however, such machinery is certainly necessary to capture (at least) the interpretation of open-scale degree-achievement changes of state such as *warm*, *cool* for which a binary $p/\sim p$ opposition is intuitively problematic. Bobaljik (2012) shows that deadjectival verbs of this class always behave morphologically as if a comparison of degrees is involved, and argues

situation of which f is the net force.)

An inchoative sentence such as *The door opened*, for example, will contain a BECOME v° head with the denotation below. In a language like English where sentences with telic predicates systematically entail completion, we propose that v introduces the presupposition that $\text{init}(f)$ is efficacious; that is, that $\text{fin}(f)$ occurs.

- (20) $\llbracket v_{\text{BECOME}} \rrbracket = \lambda p \lambda f . \sim p(\text{init}(f)) \ \& \ p(\text{fin}(f))$
presupposed: $\text{init}(f)$ is efficacious

The structure of the vP in this case is the following:³⁷



In the transitive alternant (*John opened the door*), we assume that the external argument is introduced by a Voice head, as argued by Kratzer 1996, Pylkkänen 2002, Cuervo 2003, Harley 2012, among many others. This head takes a predicate of forces as its complement and returns a function from individuals to a predicate of forces; it then composes with the external argument and returns a predicate of forces which asserts that said individual is the source of the force, whether by virtue of its inherent properties or (if animate) its intention to act.

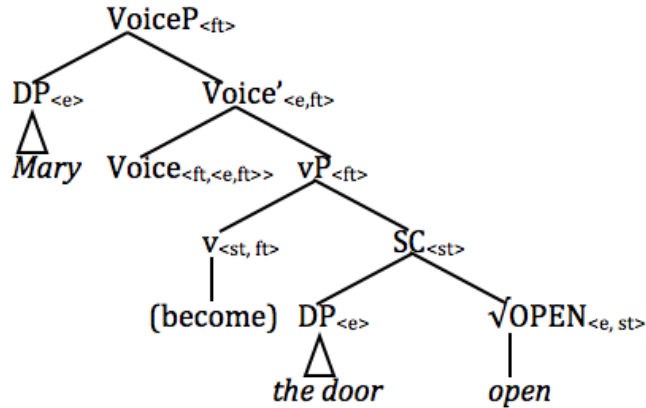
- (22) $\llbracket \text{Voice}_{\text{ACTIVE}} \rrbracket = \lambda \pi \lambda x \lambda f . \pi(f) \ \& \ \text{source}(x, f)$

The structural representation of the transitive alternant is below:

for an embedded comparative element within the vP. In such cases we assume that the small clause predicate includes this element; $\sim p$ is 'x does not have property q to a degree greater than d in s_0 ' and p is 'x has property q to a degree greater than d in s_1 ', where q is the property denoted by the embedded predicate. See also Kennedy (to appear) for related discussion.

³⁷ The category above 'open' here, $\sqrt{}$, stands for 'Root', reflecting the fact that not all change-of-state predicates are deadjectival (e.g. *melt*, *break*, etc).

(23)



Examining the types associated with each node in the trees in (21) and (23) above, we note that no special composition operation need be invoked to bring together the different parts of the complex vP; compare the special rule of Event Identification introduced by Kratzer (1996) and widely deployed elsewhere.

Note that the vP and VoiceP in these change of state predicates has the type $\langle f, t \rangle$, which is the type of a predicate of forces, that is, a dynamic predicate. We assume that what aspect applied to dynamic predicates does is to take a predicate of forces and relate it to a (reference) situation, so that the resulting AspP projection has the type $\langle s, t \rangle$. This is analogous to the familiar event-theoretic idea (e.g., Klein, 1994, Kratzer, 1998) that aspect takes predicates of events and relates them to times, though we leave open the question of how, or indeed whether, times are introduced higher in the structure. Projections higher than AspP also have the type $\langle s, t \rangle$, with Tense relating the situation introduced by Aspect to the situation of utterance.

This hypothesis about the relationship of Aspect to predicates of forces provides us with our implementation of the standard observation that certain adverbials produce ambiguity in combination with change of state predicates. In the analysis here, sentences containing such predicates will contain at least two maximal projections of type $\langle s, t \rangle$: the small clause denoting the result state (the predicate of $\text{fin}(f)$), and the AspP that is the result of composing Aspect with the predicate of forces. Adverbials which compose with predicates of situations, then, will be able to modify either of these projections, and two interpretations will result. Standard cases are *again* adverbials and *for X time* adverbials, which both compose with predicates of situations:

- (24) a. The cup was on the table again.
b. The cup was on the table for three hours.

- (25) Mary put the cup on the table again.
a. restitutive: It was on the table, then off it, then Mary put it on the table again.
b. repetitive: Mary had put it on the table before. She did the same thing again.

- (26) Mary put the cup on the table for two minutes.
 a. low reading: The cup was on the table for two minutes.
 b. high: Mary put the cup on the table several times in the space of two minutes.

We assume that adverbials such as *for two minutes* compose via Predicate Modification, though nothing particularly hinges on this choice.

- (27) a. $[[\text{again}]] = \lambda p \lambda s . p(s) \ \& \ \exists s' > \text{pred}(s) : p(s')$
 b. $[[\text{for two minutes}]] = \lambda s . \text{dur}(\tau(s)) = \text{two minutes}$

Given these denotations, these predicates will adjoin freely to the embedded small clause predicate of situations in (21) and (23) above to yield the low reading. Similarly, they will adjoin to the higher AspP, following the composition of aspect with VoiceP, to yield the high reading.

With our approach to change of state predicates in place, we can turn to an analysis of other predicate types.

4.2 Coming into and going out of existence

Change of state accomplishments are not the canonical accomplishment predicate. The cases which have been the subject of the most investigation (Verkuyl 1972, Krifka, 1989 et seq.) are accomplishments with an 'incremental theme' as an internal argument, as with the creation verbs below:

- (28) a. Mary made a painting.
 b. Mary made music.

In these cases, the direct object comes into (or, in the case of verbs of destruction or consumption, goes out of) existence, and it is the complete existence (or non-existence) of the object which determines the endpoint of the transition. In the current framework, one possibility we might consider is to treat these cases as involving a predicate of forces where the final situation is one in which an existence predicate holds. If we include this null existence predicate in the syntactic structure, as the predicate of a small clause as in (21, 23) above, however, we would predict a low-scope reading for the sentence in (29a) where *for two hours* would take the temporal trace of the existence of the painting as its argument; compare (29b) to (26a):

- (29) a. Mary made a painting for two hours.
 b. The painting existed for two hours.

There is no reading for (29a) in which the painting exists for two hours. The only reading available is the high reading, where *for two hours* adjoins to the AspP. We take this to indicate that there is no lower node of type $\langle s, t \rangle$ to which the adverbial phrase *for two hours* can adjoin.

The assertion of the existence of an incremental theme, or its non-existence in the case of destruction/consumption verbs, must therefore be semantically, rather than syntactically introduced. These verbs must then be predicates of a force which has the effect that an individual which did not appear in the initial situation exists in the final situation. We have said before that situations are

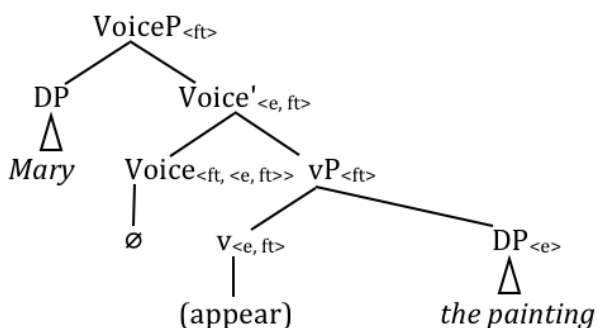
composed of individuals and their properties; we now characterize this relationship between situations and individuals for the grammar as \in . We will say that $x \in s$ holds if and only if the individual corresponding to x is in the conceptual situation corresponding to s .

An incremental theme, then, will be the complement of a v head which takes an individual and a predicate of forces whose initial situation is one in which the individual does not exist and whose final situation is one where it does. Note that we are still assuming that the external argument is introduced by the Voice head above, asserting that some individual is the source of the force; the v head itself merely asserts that an individual comes into existence. We therefore gloss it as 'appear', rather than 'make'. The denotation of this v head is given in (30) below. It ensures that the entity corresponding to x is not in the initial situation of the force, and is in the final situation of the force. As before, in English there is an efficacy presupposition associated with the v head.

- (30) $\llbracket v_{\text{APPEAR}} \rrbracket = \lambda x \lambda f . \sim [x \in \text{init}(f)] \ \& \ [x \in (\text{fin}(f))]$
 presupposed: $\text{init}(f)$ is efficacious

The structure of a sentence like that in (29a) above, then, is illustrated in (31):

(31)



The sentence in (28b) has the same structure as has the sentence in (28a), but with *music* as the complement of the v head. (28a) and (28b) however contrast in an important way that we have not yet addressed: with a bounded object such as *a painting* the predicate is telic, while with a unbounded object like *music* the predicate is atelic. One test for telicity is that telic predicates are acceptable with *in* phrases, as in (32a) while atelic predicates are marginal, or receive an inchoative reading (Vendler 1967); thus (32b), if it has any acceptable reading, can only mean that Mary started to make music at the end of an hour.

- (32) a. Mary made a painting in an hour.
 b. Mary made music in an hour.

The difference between the “bounded” and “unbounded” nature of the events in (28a,b) has been accounted for in the event-based literature via Krifka's (1992) homomorphism function, which maps subparts of incremental theme objects to subparts of events; unbounded objects thus yield unbounded creation/destruction events. Within the force-theoretic framework, this relationship will hinge on the nature of causation and its interaction with the (non-)cumulative nature of the entity whose existence is the result of the force.

To implement this idea, we first must specify what *in* phrases mean. We propose, following Higginbotham (2000) and Giorgi & Pianesi (2001), that *in* phrases specify the time between the beginnings of the temporal traces of two Davidsonian arguments; for us these arguments will be the situations referred to by $\text{init}(f)$ and $\text{fin}(f)$.³⁸ The *in* phrase adjoins to the vP which is type $\langle f, t \rangle$ (and thus, incidentally, is not compatible with stative predicates, which are type $\langle s, t \rangle$). Let “ $\tau(s_0) - \tau(s_1)$ ” be the part of the temporal trace of s_0 that does not overlap any part of the temporal trace of s_1 .

$$(33) \quad [[\text{in an hour}]] = \lambda f. \text{duration}(\tau(\text{init}(f)) - \tau(\text{fin}(f))) = \text{an hour}$$

In (32a), this works exactly as one might expect: for (32a) to be true, s_0 , the initial situation of the Mary-make-a-painting force, lasts an hour, until a painting exists, and it is at this point in time that s_1 begins.

To see how *in an hour* interacts with *Mary make music* in (32b), we have to go into a little more depth. For this explanation, it is crucial that we have nowhere claimed that a result occurs after its cause — despite any temptation one might have to read temporal relations into our bubble diagrams of causal chains of situations. Aside from the discussion of *for* and *in* adverbials, where we had to appeal to a temporal trace function and a duration function, the force-theoretic framework says nothing about times at all, and in particular, nothing about the temporal relationship between a situation and its successor; our notion of succession of a situation is a causal notion (s_1 is the result of s_0), not a temporal notion (s_1 is after s_0). In short, temporal structure and causal structure are different.

They are not entirely independent of each other, however. As Shibatani (1973) and Talmy (1976) point out, there are two temporal relationships that can exist between a cause and its effect. Either the cause provokes an effect that happens after the cause, or the cause provokes an effect that happens at more or less the same time as the cause (with at most a slight lag). Shibatani calls the first “ballistic causation” and the second “controlled causation”. Jackendoff (1990:138) points out the same notions were identified much earlier by Michotte (1946/1963), who called them ‘launching’ and ‘entraining’ causation. Talmy makes the same distinction, between “point” and “extent” causation; McCawley (1976:119) distinguishes “continuous causation”, and van Lambalgen & Hamm (2005:43-45) propose “instantaneous” vs. “continuous” causation. In continuous (or controlled, or extent) causation, temporal parts of causes are mapped to temporal parts of their effects. This mapping is analogous to Krifka’s (1992) homomorphism between events and affected objects.

We assume, then, that it is perfectly possible for the (causal) successor of a situation s_0 to happen at more or less the same time as s_0 . In (32b), for example, the initial situation s_0 (i.e. $\text{init}(f)$) includes Mary and certain of her properties, such as her intention to make music. The consequence of these properties is that she is the source of a Mary-make-music force such that some music starts to exist. But because of the mass nature of *music*, the moment there is a bit of music, then s_1 , that is, $\text{fin}(f)$, the result of the Mary-make-music force, is occurring as well; s_1 includes this music. Thus the reason that the *in* phrase is unacceptable is that there usually taken to be no interval between the beginning of s_0 and the beginning of s_1 , because of nature of the existence criteria for an non-quantized individual like

³⁸ Note that definition of force allows reference to $\text{fin}(f)$ without having to look down further in the tree than the denotation of the $\langle f, t \rangle$ node (either VoiceP or vP) that it is adjoined to; thus we avoid having either to violate compositionality (see Dowty 1979:136 on exactly this issue, in his discussion of Tedeschi’s (1973) account of progressive), or to explicitly chain Davidsonian arguments together (as Higginbotham (2000) does). It is exactly for this kind of case that we need to be able to identify a situation in terms of a force f through the use of the functions *init* and *fin*.

music.³⁹

For coerced inchoative readings for stative predicates, such as *The door was open in an hour*, where the door is understood to become open at the end of an hour, we implement a standard coercion account driven by the type difference between the *in* phrase and the stative: a head must be added that introduces a force whose final situation is a door-open situation, so that the *in* phrase can be adjoined to a type $\langle f, t \rangle$ node (for more on type-driven coercion in our framework, see section 5.2 below).⁴⁰ Type-driven coercion is not, however, available for the inchoative reading of Activities with *in* phrases, such as *Mary made music in an hour*, since the vP *Mary made music* is already of type $\langle f, t \rangle$. On the other hand, nothing in our world knowledge prevents the onset of s_0 , the causing situation of Mary's music, from beginning somewhat before the onset of s_1 . For example, Mary could have the intention to make music for a while (an hour perhaps) before starting to make music. Her intention is one of the properties in s_0 from which the Mary-make-music force arises. Then, as desired, the temporal difference between the beginning of s_0 and the beginning of s_1 is indeed an hour; in this way the inchoative reading of dynamic predicates is derived.

4.3 Manner verbs, resultatives, and motion predicates

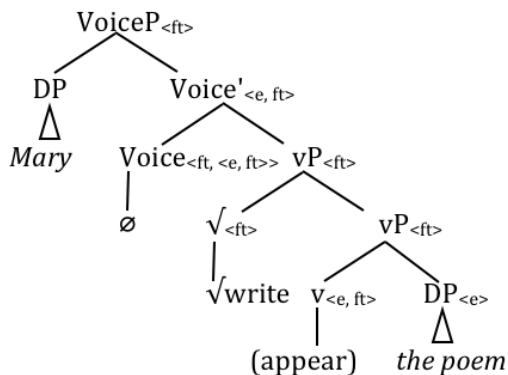
Verbs of creation and destruction are typically not as simple as 'make' or 'create', in which nothing is specified about how the creation or destruction transpires. In an articulated subevent syntax, more complex verbs are considered to modify the initiation or causation subevent (see, e.g. Levinson 2007, Ramchand 2008, Embick 2010). In the present framework, the lexical content of such verbs will be treated as predicates of forces, adding information about the nature of the force which is causing the creation or destruction of the incremental theme object.

We propose to adjoin such verb roots as manner modifiers of the vP , composing with it via Predicate Modification:

(34)

³⁹ Some incremental theme verbs, such as *read*, do not entail the creation or destruction of an object; for *read*, the relation which holds in the initial and final situation is not one of inclusion or exclusion but one of being read. The crucial claim is that the absence of a low-scope reading for *for-an-hour* adverbials in such cases indicates the absence of an embedded small clause in their syntactic argument structure representation, so that they necessarily do not involve the v_{BECOME} predicate.

⁴⁰ Why must the coercion stop with v_{BECOME} ? Why can't a VoiceP be added to introduce a source for the coerced inchoative force? I.e., why can't we then create **Mary is the door open in an hour* with the meaning 'Mary opened the door after an hour'? Part of the answer is surely that coercion only *needs* the lower v head; the higher Voice head is superfluous. But strictly speaking, we cannot rule this structure out.



Assuming that the verbal root $\sqrt{\text{write}}$ denotes a property of forces as in (35a), the denotation of the higher vP will be as in (35b); the poem does not exist in the initial situation, and does exist in the final situation, and the kind of force that brings it thus into existence is a writing force.

- (35) a. $\lambda f. \text{write}(f)$
 b. $vP = \lambda f. \sim[\llbracket \text{the poem} \rrbracket \in \text{init}(f)] \ \& \ [\llbracket \text{the poem} \rrbracket \in \text{fin}(f)] \ \& \ \text{write}(f)$

The semantics of manner modification are thus straightforward; there remains the puzzle of ensuring that the morphological content of the manner predicate ends up realized in the v head, thereby eligible for further morphosyntactic operations such as further head-movement to T, C, etc, when necessary. We propose that this is accomplished via what we might call the Matushansky gambit (Matushansky, 2006), according to which morphological Merger (m-merger) of an X° element with the head of a phrase to which it is adjoined can occur just in case the adjoined X° and the phrasal head are adjacent to each other (see Marantz 1984, Bobaljik 1994 for earlier applications of this idea, and Folli and Harley 2013 for an application to manner of motion predicates).

Indeed, this approach will suffice to analyze manner modification in contexts other than creation/destruction; since manner verbs are predicates of forces, they will always be eligible to adjoin to any node of type $\langle f, t \rangle$, and if the conditions on morphological Merger are met, thence be able to conflate with the v head and become the main verb of the clause.⁴¹ Resultatives and manner-of-motion constructions in English, as in (36a) and (36b) respectively, can be productively treated in exactly the same way. Instead of adjoining to type $\langle f, t \rangle$ predicates headed by v_{APPEAR} , such manner expressions will adjoin to type $\langle f, t \rangle$ predicates headed by v_{BECOME} :

- (36) a. Mary hammered the metal flat.
 b. Mary slouched toward Jerusalem.

⁴¹ As noted above, adjacency between the merged heads is a key condition on m-merger. This provides one motivation for treating the external argument as the subject of a higher Voice projection, rather than as an argument of an alternate form of the v head itself—a CAUSE flavor, like the BECOME head here but increased in adicity to accommodate the additional external argument (as proposed in Harley 1995, 2005, Marantz 1997, and Folli & Harley 2005). If the external argument were introduced as the specifier of vP, it would intervene between the manner modifier and the v head with which it must merge. Alternatively, if a manner predicate were merged at the v' level, it would have to type-shift freely to accommodate the different types of v in causative/inchoative alternants (*The bullet whistled past my ear / John whistled his way down the street*). These formal considerations constitute a key motivation for our adoption of the Voice head to introduce the source of forces here.

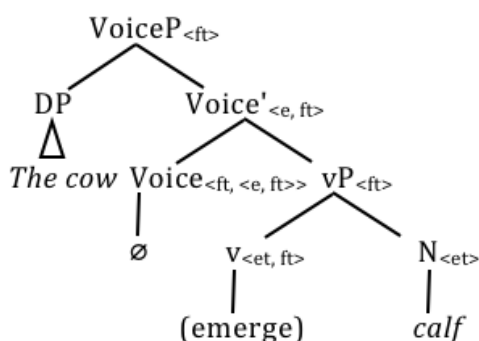
We now turn to address activities, semelfactives, and their fellow-travellers, the verbs of birthing.

4.4 Activity predicates, or, what *calving* has in common with *dancing*

We begin by examining a relatively narrow verb class first considered in detail by Hale and Keyser (1993, e.g.): denominal verbs of birthing. They propose that such predicates involve an incremental theme object which is syntactically incorporated to become the root of the verb itself, as in *The cow calved*, *The mare foaled*, *The otter pupped*.⁴² We adopt this approach to such predicates, incorporating a bare nominal predicate into a *v* head which is semantically the equivalent of *v*_{APPEAR} except in that it selects a predicate of individuals rather than an individual as its internal argument:

- (37) $v_{\text{EMERGE}} = \lambda P \lambda f. \sim [\exists y \in \text{init}(f): P(y)] \ \& \ [\exists y \in \text{fin}(f): P(y)]$
 presupposed: $\text{init}(f)$ is efficacious

(38)



Treating such objects as incorporated equivalents of incremental themes is motivated by the fact that the telicity of these predicates is sensitive to the sortal quality of the incorporated predicate of individuals: incorporated count nouns produce telic verbs and incorporated mass nouns produce atelic ones (Harley 2005). For verbs describing types of birthing, the key contrast arises between *calve* (telic) and *spawn* (atelic), but verbs such as *bleed*, *sweat* and *drool* illustrate the same point: when the produced individual is a substance, rather than a spatially-bounded item, the resulting predicate is atelic, as expected if the incorporated nominal is behaving as an incremental theme:

- (39) a. The cow calved in an hour.
 b. The mare foaled in an hour.
 c. #The baby drooled in an hour.
 d. #The wrestler bled in an hour.

⁴² The object coming into existence in transitive cases of *v*_{EMERGE} comes out of the body of the source of the force. That is, although one can *bleed* or *calve*, one cannot *poem* or *cake*. This fact suggests that there is something about the incorporation into *v* that requires the source to be the literal physical source of the object, not merely the source of the energy which provokes the coming into being of the object. We don't know why this should be so, but it will be relevant to investigation of the nature of the Source relation in future work. See Folli and Harley (2008) for discussion of the notion of 'teleological capability', which may be relevant here.

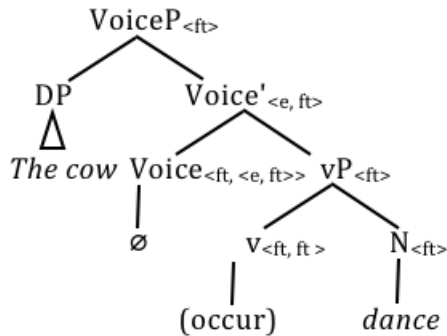
Harley (2005) claims that the intransitive analogue to such predicates (lacking the Voice projection) are denominal weather verbs, where the verb is formed from the noun denoting the emergent precipitation: *rain, snow, sleet, hail*, etc.

We are now in a position to consider the force-theoretic treatment of Activity predicates. Again, we follow Hale and Keyser (1993) in observing that such predicates are typically associated with an equivalent noun (e.g., *sing/song, work/work, dance/dance*), and that their cross-linguistic counterparts are frequently complex predicates, composed of a light verb and a bare nominal. We treat these as the equivalent of the incremental theme and verb-of-birthing cases above, again with a type-theoretic difference in the argument selected by the light verb. In these cases, we assume that the incorporated nominal is a predicate of forces, and we gloss the verbal predicate as 'occur', rather than 'emerge'. We assume that a force can be “in” a situation the same way an individual can:⁴³

$$(40) \quad \llbracket \text{dance} \rrbracket = \lambda f . \text{dance}(f)$$

$$(41) \quad v_{\text{OCCUR}} = \lambda p \lambda f . \sim[\exists f' \in \text{init}(f): \pi(f')] \ \& \ [\exists f' \in \text{fin}(f): \pi(f')] \\ \text{presupposed: } \text{init}(f) \text{ is efficacious}$$

(42)



Verbs of emission, such as *glimmer, gleam, beep, ring*, etc. are also predicates of forces in this same sense, derived from their cognate nouns. Again, the few such predicates which occur without a source-specifying Voice head are weather predicates; *thunder* is the best example of this in English.⁴⁴

⁴³ We assume that transitive Activities like *push the cart* are based on a root of type <e, <ft>>, see Harley (2005) for discussion.

⁴⁴ It is possible to make v_{BECOME} more like v_{EMERGE} and v_{OCCUR} . All three take a predicate as an argument: v_{BECOME} takes a predicate of situations p , v_{EMERGE} takes a predicate of entities P , and v_{OCCUR} takes a predicate of forces π . In the latter two cases, we have existentially bound a variable (x , and f , respectively) of which the relevant predicate is predicated. We could treat v_{BECOME} the same, and existentially bind a situation s such that $p(s)$; it requires only the assumption that a subsituation can be “in” a situation in the way an individual or a force can be in a situation. This equivalent v_{BECOME} would then have the denotation in (ib) instead of the one we proposed above in (20), repeated here as (ia):

(i) a. $v_{\text{BECOME}} = \lambda p \lambda f . \sim p(\text{init}(f)) \ \& \ p(\text{fin}(f))$ (= (20))
b. equivalent $v_{\text{BECOME}} = \lambda p \lambda f . \sim[\exists s \in \text{init}(f): p(s)] \ \& \ [\exists s \in \text{fin}(f): p(s)]$

However, we continue to prefer (ia) because it is simpler (and see also footnote 67 below).

This analysis of Activities, it should be noted, refers to a similar causal structure as the analysis of Accomplishment predicates: the predicate refers to a force that provokes another situation. However, our Activities differ from our accomplishments in two ways. The first is that the N complement of *v* is a predicate describing a force that is instantiated in the result situation, rather than a result-state predicate of that situation, like [the door open]_{SC}; this in turn means that *v*_{OCCUR} is type-theoretically distinct from *v*_{BECOME}.

The second way in which Activities differ from Accomplishments in the force-theoretic framework is that the temporal relationship between the causing force and the effect is different, as we proposed above in section 4.2. We propose that continuous causation is what happens in Activities: the result happens simultaneously with the causing force, instead of afterward. The temporal simultaneity is crucially not expressed in the semantics; the logical form makes no reference to temporal structure at all. Rather, it is a fact about the world that the particular force has a result that occurs either after or at the same time as the force itself.⁴⁵

This dissociation of the causal structure from the temporal structure may not be plausible in a theory based on events, to the extent that it is implausible to think that there are two distinct events going on at the same time during an (e.g.) dancing event. (One theory with two Davidsonian arguments in Activities, that of Ramchand 2008, crucially places the events in a temporal sequence.) However, in a force-theoretic framework, it is not implausible to think that there is an exertion of energy in a dance-like manner, that results, more or less simultaneously, in a situation where there is a dance.

Semelfactives such as *knock*, *flash*, and *pat* (Smith 1991) are like Activities in that they name predicates of forces, and occur as complement to *v*_{OCCUR}. Semelfactives, however, impose an additional requirement on the subsequent situation *s*₁: The *s*₁ of the force named by a semelfactive verb is required *not* to be a situation with an instance of a verbing force in it; this requirement gives semelfactives their 'cyclic' quality, as noted by Talmy (1985). Activity predicates do not have such a requirement.

Again, as predicates of forces these verbs are predicted to participate freely as manner predicates in change of state and resultative constructions (i.e., with *v*_{BECOME}), and are equally expected to appear as activity predicates (i.e., with *v*_{OCCUR}), a pattern which has long been observed in the lexical-semantic literature:

- (43) a. She hammered.
 b. She hammered the metal flat.
 c. She laughed.
 d. She laughed him out of the room.

Indeed, they are equally predicted to participate as manner predicates in incremental theme constructions (i.e., with *v*_{APPEAR}), producing the well-known hyponymous object and cognate object cases:

- (44) a. She danced a jig.

⁴⁵ As is well-known, there is a coerced reading of Activities with *in an hour* modifiers, (e.g., *Mary ran in an hour*) to the effect that there is a specifically planned satisfactory amount of running that Mary did in an hour. This is a case, like ordinary incremental-theme telics, where the result—here the point where Mary's running reaches an agreed-upon or accommodated standard—occurs at the conclusion of the application of the Mary-running force. That is, a sortal/quantized interpretation is imposed on the incorporated predicate of forces. The same would apply to *Mary made music in an hour*, etc.

- b. She sang a song.

Verbs of birthing can also participate in cognate object/hyponymous object incremental theme constructions, as in *She calved a beautiful heifer* or *She sweated bullets/blood/Gatorade*; similarly, in robust manner-incorporating languages like English, they can occur as manners in change-of-state structures:

- (45) a. She sweated her way to Carnegie Hall.
b. He bled to death.

In the framework here, the well-formedness of such cases (which are subject to cross-linguistic parameterization) must result from a type-coercion operation which lifts these predicates of individuals into predicates of forces, enabling them to behave as manner modifiers.

This latter observation raises the possibility that all of these nominal verb roots (including *dance*, *sing*, etc.) are predicates of individuals that are type-shifted to predicates of forces when they appear as manners. In that case, v_{EMERGE} would be used for both the birthing and activity verb classes. However, there are empirical reasons to think that the ontology of nominal predicates needs to include both predicates of individuals and predicates of forces. Activity roots in the event-based literature are treated as predicates of events (see, e.g. Marantz 2001 Levinson 2007, Embick 2010) because the corresponding nouns interact differently with predicates like *begin*. Nouns like *dance* can serve as subjects of *begin*: *The dance began (at 2 o'clock)*. Nouns like *calf* or *cake*, however, cannot: *#The calf began (at 2 o'clock)*. (See Pustejovsky 1995, Pylkkänen et al. 2009 for further discussion of *begin* as a rigid type selector.) In this framework, such facts motivate our treatment of activity roots like *dance* or *sing* as predicates of forces, type $\langle f, t \rangle$.⁴⁶

It is worth noting that the conception of Activities as creations of forces circumvents one issue related to the characterization of Activities in situation semantics. Considerable attention has been devoted to the notion of a ‘minimal situation’ in that literature (Kratzer 1989, Heim 1990, Portner 1992, Kratzer 1998, Cipria and Roberts 2000). A problem that arises for Activity predicates in situation semantics is that they allow gaps in their run time—for example, in a *Mary dance* situation, Mary does not need to dance constantly throughout—so there would seem to be no way to define a minimal situation in which an activity predicate is true, i.e., one that contains all and only the elements required for the truth of the predicate. It is to solve this problem that Kratzer (1998) proposes the idea of a situation that ‘exemplifies’ a proposition. In our proposal, in contrast, the problem of defining a minimal situation does not arise: when Mary dances for two hours, she is the source of a force, stemming from her intention, in whose two-hour-long final situation there is dance. There can therefore be temporal gaps between instances of dance within that situation; there is no need to define a minimal dancing situation based only on the temporal traces of Mary’s activity.

Another welcome result of treating activities as referring to the final situation of a force is that it suggests a characterization of Japanese *-te iru*. As, e.g., Ogihara (1998) shows, *-te iru* tends to be translated as the English progressive in combination with activities, as in (46a), and as a resultative with

⁴⁶ Roy and Soare (2013) present an argument that the event involved in such nouns is at the conceptual or lexical level, while grammatically they are predicates of individuals (type $\langle e, t \rangle$). We will not take up this idea here although we find it interesting, especially as, given the dual nature of forces as functions (in the linguistic system) and inputs of energy (in the conceptual system), we also need to make reference to a mapping from logical form to a conceptual level that is not the lexicon. See Copley & Harley (in prep.).

telic predicates, as in (46b).

- (46) a. Taroo-wa warat-te iru.
Taroo-TOP laugh-te iru
'Taroo is laughing.'
b. Taoru-wa kawai-te iru.
towel-top dry.intr-te be
'The towel has dried.'

Ogihara's unification of these readings, in (47a) below, takes advantage of partial events, saying that a *-te iru* sentence is true when an event occurs at the reference time and *e* is a part of a larger event. A more recent account of *-te iru* (Nishiyama, 2006) is rather similar to Ogihara's, but uses both partial events and inertia worlds as per Portner (1998). These give the meaning of *-te*, as shown in (47b,c), while *i(-ru)* denotes mapping from events to states.

- (47) a. $[-te\ iru]$: For any predicate Φ , individual a , eventuality e , and interval t , $[\Phi-te\ iru](a)(e) = 1$ at t iff there are eventualities e and e_1 such that the temporal trace of e equals t and $e \subset e_1$ and $[\Phi](a)(e_1) = 1$.
b. The function of *-te*:
When Φ is an eventuality description which is either a telic event-type description or an atelic event-type description,
 $\Phi-te$ is true if and only if:
i. there is an e' such that $e' \leq e$, $\tau(e') \prec r$ (r is a reference time interval) and
ii. e satisfies $MAX(\Phi)$ in all inertia worlds, i.e. in all worlds which are relevant to whether e is completed and in which e does not get interrupted. c.
MAX: For all eventuality descriptions Φ and events e , $MAX(\Phi)(e) \leftrightarrow \Phi(e)$
 $\wedge \forall e'(e < e' \rightarrow \neg \Phi(e'))$

However, as we have seen, the move to partial events is problematic in that nothing is said about the conditions under which one event can be 'part of' another, when the culmination of the larger event may or may not happen. The move to inertia worlds may be problematic in the other direction: there is a lot of semantics in the logical form that could (and, we think, should) be put into the cognitive system.

In our framework, the denotation of *-te iru* need only say of the reference situation that it is the final situation of a force with the desired property. Recall that "pred(s)" picks out the predecessor situation of *s*.

- (48) $[[-te\ iru]] = \lambda \pi \lambda s . \pi(\text{net}(\text{pred}(s)))$

For a telic predicate, the final situation is the result state that begins after the initial situation, yielding the resultative interpretation, while for an Activity, the final situation is a situation that is almost entirely cotemporaneous with the initial situation, so these cases receive an ongoing reading.⁴⁷

⁴⁷ A third reading is an 'experiential perfect' (Comrie 1976) reading:

- (i) Taroo-wa zyuk-ken-mo ie-o tat-te iru.
Taro-top to-cl-as.many.as house-acc build-te be-pres

4.5 Agents and Causers as sources of forces

Thus far, we have treated the external arguments of all Aktionsart types identically, namely, as the subject of a 'source' predicate expressing a relationship between an individual and a predicate of forces, introduced by the Voice head.⁴⁸ We now provide some explication of our notion of 'source', connecting it to the literature on external argument thematic relations more generally, and to the continuous/ballistic causation distinction from the force-dynamic literature which has already been alluded to above.

Animate and inanimate external arguments can exhibit distinct interactions with argument-structure and Aktionsart classes. The literature on thematic relations has examined this distinction in detail, without coming to any consensus on the qualia that underlie these interactions. A common distinction is made between volitional and non-volitional entities, which are often termed "Agents" and "Causers" respectively (of course, a volitional entity can be a Causer if its action is non-volitional). The Agent/Causer distinction also bears on the Aktionsart type of the predicate: Causers seem to be more restricted, in that they typically only appear as the external arguments of change-of-state predicates, while Agents can also be the external arguments of Activity and Semelfactive predicates.

Analyses differ, however, on whether such distinctions are taken to be visible in the grammar. Ramchand (2008), for example, subsumes all external arguments under a single 'Initiator' role. Hoekstra (1984) and Higginbotham (1985) deny any particular relational content to the external argument role at all: external arguments are simply notationally designated as such, without giving an event-structural or thematic 'name' to their relationship with the predicate. In contrast, Beavers and Zubair (2013) propose that the Agent/Causer distinction depends on whether the effector of a change is a dynamic or a stative event.

So far in our development of the force-theoretic framework we have made a similar assumption, treating both Agents and Causers as sources of forces. We use the term 'source' in quite a literal sense to indicate that in both cases, the argument introduced by Voice is the origin of the energy that is put into the situation; they thus play a 'leading role' in determining the net force of the situation. There is at least one way in which Agents are distinct from Causers, which is that they become the sources of forces by virtue of their intentions, rather than by virtue of their physical properties. Copley and Harley (to appear) formulate a Law of Rational Action to mediate the relationship between having an intention and generating a force (see also Kamp, 2007 and Copley, 2010 for explicit proposals for linking intentions to actions). Agents are subject to the Law of Rational Action because they have the ability to intensionally represent a goal. Another obvious difference is that Agents have the ability to create energy spontaneously (as if by magic), while, for instance, a thrown object is dependent on its motion and mass for the (kinetic) energy it provides to the situation. In general, we expect that distinctions which in previous work have been ascribed to the distinction between Agents and Causers have their basis in

'Taro has built as many as ten houses.'

While we have nothing to say about what causes an experiential perfect reading as opposed to a resultative one, we note that the latter has an equal claim to being a result situation of a force.

⁴⁸ Note that we do not appeal to syntactically-expressed chains of subevents: the difference between a causative and an inchoative verb is simply the explicit inclusion of a source argument, introduced by an active Voice head. Anything that looks like chaining emerges from the semantics for forces.

facts about the relative abilities of Agents and Causers. We discuss the two aforementioned special abilities of Agents here, beginning with the notion of energy-generation and its connection to ballistic vs. continuous causation and Aktionsart classes, and then returning to briefly investigate some consequences of volitional Agents' ability to intensionally represent goals.

Agents can be the external arguments of Activities as well as change-of-state predicates, as in (49a). In contrast, Causers cannot be the external argument of Activities, as reflected by the need for the telicizing resultative adjective *raw* in (49b) (Folli and Harley 2004, among others).

- (49) a. John rubbed his skin.
b. The saddle rubbed his skin *(raw).

Recall that Activities in the force-theoretic framework involve what McCawley (1976) and van Lambalgen and Hamm (2005), e.g. call “continuous causation,” where a result situation occurs at more or less the same time as the initial situation, perhaps with a brief initial lag. We would like to suggest that the explanation for the contrast in (49) turns on the idea that the ability to generate energy throughout a situation is necessary for continuous causation (compare the notion of 'event-to-event' homomorphism from Levin and Rappoport Hovav (2005), Rappoport Hovav (2008)). Beavers and Zubair (2013) show that in Sinhala, so-called 'volitive' marking depends on exactly the property of being able to generate a dynamic eventuality, which maps naturally to the notion we are discussing here.

Volitional entities have the ability to generate energy quite generally; Folli and Harley (2008) have argued that the notion of Agent should be extended to include certain special inanimate objects which are 'teleologically capable' of generating the energy needed to produce certain specific forces (e.g., *The kettle whistled*, *The wind moaned*). This energy arises also in a kind of magical way, in that it is not perceptibly transmitted spatiotemporally from other objects. However, unlike for volitional Agents, it is not generated in response to the interaction of intentions with the Law of Rational Action. Consequently, such inanimate but teleologically capable Agents are more constrained in the kinds of forces they can generate; in typical examples it is only the one or two kinds of forces they were designed to produce (in the case of artifacts) or stereotypically do (as in the case of the wind, the sea, etc.).

Like the ability to generate energy, the ability to represent a goal will also have repercussions for the kinds of forces that can be generated by an entity. It is the Agent's representation of the goal that unifies the disparate sub-forces of picking up a pen, cogitating, writing, redacting, etc. into something we understand as a "write-a-poem" force with a final situation in which a poem exists; a Causer cannot write a poem because it lacks the intention that would glue these subforces together as goal-directed action (see also Tovenia 2011, e.g. for a related idea). Likewise, an activity of getting paint on something is only 'painting' if there is an Agent that intends it to be (*#The explosion at the paint factory painted it*, Kiparsky (1997), see also McCawley 1971, Fodor 1981). The ability to intensionally represent goals also proves crucial to futurities such as *The Red Sox play/*defeat the Yankees tomorrow*, as in Copley (2008, in press), and *have-causatives* (Copley & Harley 2010).

The properties that Agents have of being able to generate energy and (for volitional Agents) of being able to represent a goal can therefore account for contrasts between Agents and Causers. For the cases we have discussed, we need not posit that the grammar has access to these properties; rather, these are simply constraints on the kinds of forces that can be produced by any particular entity, on the

basis of its abilities.⁴⁹ Copley & Wolff (to appear) further develop this point to argue that the key property that subsumes both Agents and Causers is that of causal disposition, where volitions are a special kind of disposition.

If this conceptual story is the whole story, we would expect that argument structure would not be sensitive to any distinction between Agents and Causers, in particular, the ability to represent goals intensionally should not be visible to the grammar. So far, the only thing the grammar sees is the *source* relation, which pertains to Agents and Causers alike. If this is the case, however, something more should be said about the status of a certain body of empirical evidence that seems to suggest the need for an Agent/Causer distinction in the grammar.

4.6 Cause-introducing PPs

One set of arguments for a distinct Causer or Cause role comes from the debate over anticausativization approaches to inchoative predicates. As we will see, it has been argued that certain data from adjoined PP phrases pick out all and only Cause arguments in dynamic predicates.⁵⁰

The *by*-phrase in a passive introduces exactly the set of external arguments that active Voice can (Williams 1981), and is ill-formed with unaccusative predicates (see Bruening 2012 for a recent account). In contrast, *from*-phrases seem to introduce only Cause external arguments, and are well-formed with unaccusatives. This range of facts is illustrated in (50). The *by*-phrase can introduce anything that can be the external argument of the corresponding transitive active clause, but cannot co-occur with the unaccusative. In contrast, *from* can only introduce non-agentive external arguments: the sentence in (50c) is not felicitous in a case where John is the Agent of an action that warms up the sidewalk (though it is acceptable if it is his body heat that warms the sidewalk).

- (50) a. The sidewalk was warmed up by John/by the sun.
 b. The sidewalk soon warmed up from the sun.
 c. #The sidewalk warmed up from John.

This compatibility of *from*-phrases with inchoatives, and the special constraints on the kind of arguments that *from*-phrases can introduce, have been taken to show the need for causing events in the semantic representation of inchoative predicates, and such data has been central to the anticausativization vs. causativization debate over the causative/inchoative alternation. (Chierchia 1989/2004, Pinon 2001, Alexiadou, Anagnostopoulou and Schäfer 2006, Kallulli 2006, Schäfer 2007, among many others)

Along the same lines, Chierchia (1989/2004), introduces another test which he claims picks out all and only sentences with either Agent or Causer subjects: the availability of *by Xself* adverbials. Levin and Rappaport-Hovav (1995), Koontz-Garboden (2009) and Beavers and Zubair (2013) also adopt this diagnostic. Since *by Xself* is possible with inchoative predicates such as the one in (51), Chierchia

⁴⁹ It is plausible to think that grammaticization of the inherent force-generation ability is how cases of animacy-marking might arise, just as grammaticization of natural gender produces gender-marking. This would be consistent with the observation that natural forces are typically classed as 'animates' in languages which mark animacy.

⁵⁰ Causes, as discussed in the event structure literature, seem to be a subset of the argument which in the thematic role literature are called Causers; in particular, Causers include all non-volitional initiators of changes of state, while Causes are specifically only the events which are the first argument of a CAUSE relation.

concludes that inchoatives are underlying two-place causative relations with the external Causer role bound by reflexivization to the internal Theme role (with reflexivization overtly marked in languages like Italian).

(51) The door opened by itself.

We argue, in contrast, that neither *from*-PPs nor *by Xself* PPs actually indicate the presence of a causer or causing event in the semantics of these predicates. With respect to *from*-PPs, our contention is based on the little-commented-upon fact that such PPs can modify stative predicates, as well as dynamic ones:

- (52) a. The sidewalk was warm from the sun.
b. John was pink from embarrassment.

It would seem implausible to analyze stative predicates like *be warm* or *be pink* as introducing a causing eventuality argument in addition to the eventuality argument representing the state; they do not behave like dynamic eventualities (#*The sidewalk was being warm*; #*John was being pink*., etc.) Consequently, it seems clear that *from*-PPs do not *diagnose* the presence of a Cause argument in the semantics of the predicates to which they adjoin (though they may *introduce* one).

Similarly, Alexiadou, Anagnostopoulou and Schäfer (to appear), in line with the conclusions of Piñon (2001), Alexiadou et al (2006), Schäfer (2007) a.o., argue at length that *by Xself* phrases do not diagnose all and only predicates with Agent or Causer subjects. They give examples where the antecedent of *by Xself* cannot be a causer, as in adjectival copula constructions:

- (53) 300 million years ago the climate became warmer by itself and without human intervention.

They conclude, with Reinhart (2000), Pylkkänen (2002), among others, that *by Xself* simply denies the participation of any identifiable Agent or Causer; in the current framework, it would deny the existence of a Source argument for the net force of the preceding situation. They conclude that anticausative predicates lack an implicit external argument of any kind. (See also Schäfer and Vivanco (2013) for explicit argumentation against Koontz-Garboden's reflexivization approach.)

While we will not provide a full treatment of the properties of these PP adjuncts here, the tools made available in the force-theoretic framework do suggest an intuitively plausible line of analysis for the *from*-PPs. The event-theoretic literature has argued that the DP argument introduced by a *from*-PP names a causing event; this corresponds here to the natural idea that such a DP names a force (remember we used a similar idea above in section 4.4 in discussing the meaning of NPs such as *dance*). In this light, consider the data in (54) below. (54a) and (54b) contain DPs that seem like good candidates for names of forces; both DPs are felicitous in a *from* PP. *The ball* (54c) seems to just possibly be elliptical for *the action/motion/energy/force of the ball* and in that case, the *from* phrase is just possible. (54d) is infelicitous, even if we try to understand it thus elliptically; *the elephant* cannot be elliptical for *the force exerted by the elephant*. The ill-formedness in (54e) is similar to the ill-formedness in (54d). In the last two (or three) examples, the name of an Agent cannot be elliptical for

the name of a force exerted by that Agent.⁵¹ In short, *from*-phrases require as arguments DPs that name forces.

- (54) a. The window broke from the earthquake
 b. The window broke from the ball's hitting it.
 c. ?The window broke from the ball.
 d. The floor broke from the *(weight of the) elephant.
 e. The window broke from John*('s hitting it).

It is also worth noting that such *from*-phrases are compatible not just with causative change-of-state predicates (as suggested by the 'cause' analysis in the event literature) but also with unergative predicates, as in (55), as long as the force named by the DP argument of *from* (i.e., f_{-1}) directly provokes the force described by the predicate (f_0). There are two ways that this can happen, depending on whether source of f_0 generates the force by virtue of the Law of Rational Action (i.e., voluntarily), or by some other means (i.e., involuntarily). If the source is voluntary, as in (55c, d), then f_{-1} can only be a desire or volition;⁵² this is the same as saying that in voluntary action, the most immediate “cause” of the force is always volition. If, on the other hand, the source is involuntary, then f_{-1} can be something other than a desire, as in (55a,b).

- (55) a. Mary cried out from anger.
 b. John groaned from the pain.
 c. Sue called John from a desire to see how he was/#from the pain.
 d. The university was shut down (by the governor) from a desire to protect the students/#from the riots.

Insofar as it is plausible for DPs to be names of forces as well as individuals (just as, in the event-theoretic literature, DPs can name events, pronominally refer to events, etc.) the force-theoretic framework gives us the tools needed to address the range of facts here. A *from*-PP adjoins to a predicate of situations (presumably AspP, as do *for*-PPs, see section 4.1 above) and introduces a relation between the force named by its internal argument and a situation s , namely that the force was the net force of the situation preceding s :

- (56) $[[\text{from}]] = \lambda f \lambda s . \text{net}(\text{pred}(s)) = f$

Such force-naming DPs can also serve as external arguments introduced by the Voice projection, as in *The earthquake broke the window*. In event-theoretic approaches (e.g. Bach 1986) events are analogous to individuals; in the present framework the same will be true of forces (though see fn. 46 for further discussion).

⁵¹The exact conditions on this kind of ellipsis require further investigation, but we note that it seems to be impossible to understand an individual-denoting DP as an elliptical name for a force when the force is produced by the interaction of the individual with the normal field (Copley & Harley, to appear) via either the gravitational field, as in (54d), or the Law of Rational Action, as in (54e)), as opposed to a (more) direct transmission of energy.

⁵² Recall that we wish to treat desires as properties of an individual that nevertheless have a (second-order) force-like nature of their own, i.e., as dispositions; see Copley & Wolff (to appear) and section 2.2.3 above.

5. Dynamic and stative predicates

Now that we have presented our implementation of the syntax-semantics interface for verbal argument structure, we take a step back to consider the relationship between the technical apparatus presented here and Davidson (1967)'s original data. One of the major kinds of evidence supporting the reification of events was the interpretation of adverbial modifiers. We differ from Davidson in what we think the arguments he discovered really are—as we have argued above, we consider them to be reified forces rather than reified events—but we are good (neo-)Davidsonians in supporting modification by means of arguments.

While Davidson's article explicitly treated only what he called "action sentences", it was evident that certain stative sentences can also pass many of his modification tests; this has been taken to show (e.g. Kratzer, 1995) that such statives have to have a Davidsonian argument as well, as shown in (57):

(57) Mary was happy in the living room.

However, it is clear that not all modifiers are created equal. Thomason and Stalnaker 1973 pointed out that certain adverbials which are good modifiers of action sentences (e.g. *quickly*) cannot modify stative sentences, and proposed to distinguish the two types of predicates with a diacritic to which adverbial modification is sensitive. However, they did not introduce a clear type-theoretic contrast to distinguish these two classes of eventualities.

We would like to draw attention to the fact that the force-theoretic framework provides a more fine-grained ontology for Davidsonian arguments.⁵³ We have two types of arguments that can serve Davidson's purposes, situation arguments and force arguments. In fact, we have already made use of this distinction in accounting for the distribution of two temporal adverbial phrases: *for*-phrases (see (27b)) take situation arguments, while *in*-phrases (see (33)) take force arguments. This gives us the ability to attack the so-called 'eventive' vs 'stative' distinction with type-theoretic tools, though for reasons that should be evident, we will prefer the term "dynamic" to the term "eventive" when referring to non-stative predicates.

In this section, we will analyze several of the conundrums related to this distinction in terms of our type-theoretic difference between forces and situations. We will first show that it is easy to analyze Katz's (2003) generalization about Thomason & Stalnaker's two classes of adverbials. We then provide an implementation of aspectual coercion in response to type clash with the selectional requirements of progressives and imperatives. We subsequently demonstrate that the force/situation distinction gives us the tools needed to propose a novel formal analysis of a mainstay of the force-dynamic literature: 'maintaining' predicates such as *keep* and *stay*.

⁵³ Of course, we need to consider as well whether it is *too* fine-grained. An anonymous reviewer reminds us that one of the attractions of Davidson's proposal was a simplified mapping between nominal and verbal modification: adjectives and adverbs are both predicates of a basic-type argument, either an individual or an event. The ontology we adopt here is more complex. On reflection, we expect mappings between predicates of individuals and predicates of situations to be as straightforward as it was for Davidson. The only issue arises when we consider how modifiers of predicates of *forces* might map to the nominal domain. But note that the adjectival form *quick* of the predicate of forces *quickly* combines only with nominals which themselves are felicitously treated as predicates of forces, as diagnosed by, e.g., the *begin* test (see discussion in section 4.4 above). Compare, e.g., *a quick lunch* with *#a quick calf*. This being the case, it seems that the finer-grained division we propose here are likely to be appropriate in the nominal domain as well as the verbal domain.

5.1 Adverbial selection

As alluded to above, Thomason and Stalnaker (1973) observed that certain adverbial modifiers (what they called 'VP-adverbs') are incompatible with stative predicates, although others ('S-adverbs') can modify both stative and dynamic predicates:

- (58) a. *John loved Mary quickly.
b. John kissed Mary quickly
- (59) a. John probably loved Mary.
b. John probably kissed Mary.

They proposed that the sensitivity of VP-adverbs such as *quickly* to the difference between stative and dynamic predicates indicates that there is a need to distinguish the two classes via a diacritic visible to VP-adverbs.

Katz (2003) points out that there is a crucial asymmetry in the classes of adverbs which are sensitive to this feature. While there are adverbs which modify dynamic predicates and are incompatible with stative predicates, as in (60), there are no adverbs exhibiting the reverse pattern, compatible with only stative predicates -- the pattern illustrated in (61) does not occur, i.e. there is no adverb with the distribution of *blickly*. All adverbs capable of modifying stative predicates can also modify dynamic ones, as in (62). Katz calls this the Stative Adverb Gap.

- (60) a. John kissed Mary quickly.
b. *John knew Mary quickly.
- (61) a. *John kissed Mary blickly.
b. John knew Mary blickly.
- (62) a. John kissed Mary a long time ago.
b. John knew Mary a long time ago.

What's needed to account for the Stative Adverb Gap is for dynamic predicates to share something with stative predicates, so as to enable combination with adverbs like *a long time ago*, but also have an additional property, which stative predicates lack, that allows them to combine with adverbs like *quickly*. The failure to combine should be the product of a type-clash. Katz proposes that statives lack a Davidsonian event argument.⁵⁴ From this it follows that only dynamic predicates are compatible with adverbials that select for event arguments (i.e. Thomason and Stalnaker's VP-adverbs). But since both dynamic and stative predicates ultimately become predicates of times higher in the structure, they are both modifiable, at these higher nodes, by temporal adverbs.

The force-theoretic framework also provides a type distinction between dynamic and stative predicates on which such adverbial selectional behavior can depend: dynamic predicates are predicates of forces, while stative predicates are predicates of situations.⁵⁵ As in Katz's approach, it further

⁵⁴ Incidentally, Davidson (1967) himself tentatively concludes that not all predicates have an event argument (p. 94), giving the stative sentence *I had my thirteenth birthday* as one example.

⁵⁵ Beavers and Zubair (2013) also propose to distinguish type-theoretically between states and events, while

automatically provides the shared property, because predicates of forces become predicates of situations via the operation of Aspect.⁵⁶ Consequently, we expect any adverb that can compose with stative predicates to also be able to compose with dynamic predicates, a property we already have seen above in our treatment of *for*-modification (section 4.1).

Because stage-level stative predicates in the force-theoretic approach have a situation argument, it is possible that the present analysis has an advantage over Katz's, in allowing us to maintain Kratzer (1989)'s distinction between stage and individual level stative predicates, which is lost in Katz's approach. In the current proposal, stage-level statives have a situation argument, and hence also a temporal trace, and we can happily assume that individual-level statives are predicates of individuals, as Kratzer proposed.⁵⁷

5.2 Coercion

As Katz shows, the availability of a type-distinction between stative and dynamic predicates also has significant advantages in accounting for the dynamic readings acquired by some stative predicates in morphosyntactic frames that normally require dynamic predicates. For example, although the English progressive was one of Vendler's original tests for stative vs. dynamic predicates (as in (63)), it has long been recognized that certain predicates thought to be stative because they can occur in episodic readings with the simple present, as in (64), can indeed occur with the English progressive, as in (65) (Partee 1977, Dowty, 1979, Smith 1983, Bach, 1986, de Swart 1998):

- (63) a. John was smoking.
b. #John was knowing French.
- (64) a. Mary loves her new neighbors.
b. John is very smart about this.

maintaining the overall notion of a supercategory of 'eventualities'; however, their implementation does not obviously allow for the capture of the one-way implicational relation between the categories that Katz's data requires.

⁵⁶ An anonymous reviewer points out that not all adverbials that combine with both stative and dynamic predicates plausibly combine above Aspect, e.g., *intentionally*, which refers to properties of the subject argument and therefore might naturally be thought to adjoin below Aspect. In that case, such adverbs must have two types, <s,t> and <f,t>. We don't see this as a problem, however, since this point pertains only to adverbials that are related to the subject's intentions such as *regretfully*, *considerately*, etc. There is independent evidence that intentions and their results can be either stative or dynamic, and that the stative-dynamic difference, even for intentions, is visible to the grammar. See the discussion on the representation of goals in section 4.5, and the contrast in (i), which shows that *have* causatives (which encode the matrix subject's intention) can be either stative or eventive, and that this difference affects aspectual selection in the usual way.

- (i) a. Mary has/*is having John running errands.
b. Mary has/is having John run errands. *has on episodic reading

We conclude that it is appropriate to allow adverbials like *intentionally* to modify both stative and dynamic predicates.

⁵⁷ It is possible, also, that treating stage-level statives as predicates of situations, rather than predicates of times, provides (like Kratzer's) a more perspicuous account than Katz's of certain non-temporal adverbials that can modify such predicates: In a sentence like *Mary was happy in the kitchen*, for example, it seems that the Davidsonian argument being modified by the location predicate is not obviously temporal in character.

- (65) a. Mary is loving her new neighbors.
b. John is being very smart about this.

Likewise, some stative predicates can occur in imperatives which are also supposed to select dynamic predicates, as shown in (66) and (67):

- (66) a. Smoke!
b. #Know French!
- (67) a. Love thy neighbor!
b. Be smart about this!

Rather than multiply lexical entries to account for the apparently variable eventiveness of these predicates, we assume (with Smith 1991, de Swart 1998, a.o.) that these are examples of coercion. Other prototypical cases of coercion have been profitably treated as type-driven; for example, sentences like *John began the book* arguably coerce an entity into an event (Pustejovsky 1995, Pylkkänen et al. 2009); see also Bale and Barner (2009) on coercion between count and mass readings of bare nominals. In event-based frameworks without a type distinction between stative and eventive predicates, the coercion of a stative to an eventive predicate cannot be treated as type-driven.

We can take advantage of the present type-theoretic distinction between stative ($\langle s, t \rangle$) and eventive ($\langle f, t \rangle$) predicates to motivate an account of coercion in progressive statives. The progressive, we proposed above in (18), selects an $\langle f, t \rangle$ predicate. When a progressive or an imperative is applied to a stative predicate like *John love Mary*, the type mismatch triggers a type shift from $\langle s, t \rangle$ to $\langle f, t \rangle$.⁵⁸

It is worth noting that although it has been claimed that the subject of coerced stative progressives has to be volitional, this is not actually the case. Rather such subjects are restricted by the usual constraints on the external arguments of Activity predicates discussed in section 4.5 above. While they need not be volitional, they must exhibit teleological capability because the result of such coercion is an activity. In examples like *John is not being smart about this* or *Mary is being silly*, the Activity can certainly be non-intentional; cf. also *The sea is being awfully aggressive today*.

5.3 Verbs of maintaining

The third case in which the force-based treatment provides formal insights into the dynamic-stative distinction involves a classic case from the cognitive force-dynamic literature, namely verbs of maintaining. They are canonical examples of the way in which lexical meanings refer to agonist/antagonist relationships, revealing the need for a Davidsonian argument that refers to a force rather to an event. Above we outlined the issues raised by such verbs, like *keep* and *stay*, which are clearly dynamic (as shown by examples (8, 9) above, repeated below as (68, 69)) but which do not involve a change of any kind.

⁵⁸ We here remain agnostic concerning the mechanism by which the type shift is implemented, whether purely in the semantic representation or whether by means of an additional layer of structure. We also leave for future research the question of the conditions under which this shift is possible.

- (68) a. The rock is keeping the door open.
b. The door is staying open.

- (69) a. The rock keeps the door open.
b. The door stays open.

These verbs are paradigm cases in the cognitive linguistics literature on force dynamics, but are not often discussed in event-theoretic approaches.

We can imagine several event-based analyses for *keep*, but they seem unsatisfactory. We assume that *keep* and *stay*, like other causative predicates, take a small clause complement. In a sentence such as *The rock kept the door open*, this complement would be [the door open]). The problem with event-based (70a) (“cause to be”) and (70b) (“cause to become”) is that it is possible to keep something in a location without strictly being the cause of its being there or of its coming to be there. On the other hand, *keep* might instead be “cause to stay,” as in (70c). But in considering an event-based approach to *stay*, as in (70d), we run out of options: there can be no external argument or causing event, and there is no obvious way to combine the caused event and the proposition denoted by the small clause in such a way as to reflect the fact that *stay* is not the same as *be*.

- (70) a. $[[\text{keep}]](x)(p) =? \text{Agent}(x, e_1) \ \& \ \text{CAUSE}(e_1, e_2) \ \& \ \text{BE}(e_2, p)$
b. $[[\text{keep}]](x)(p) =? \text{Agent}(x, e_1) \ \& \ \text{CAUSE}(e_1, e_2) \ \& \ \text{BECOME}(e_2, p)$
c. $[[\text{keep}]](x)(p) =? \text{Agent}(x, e_1) \ \& \ \text{CAUSE}(e_1, e_2) \ \& \ [[\text{stay}]](e_2, p)$
d. $[[\text{stay}]](e_2)(p) \neq \text{BE}(e_2, p)$

What is needed is a way to represent the idea that dynamic predicates involve the input of energy into a situation, rather than a change, which is exactly what we have been advocating. The intuition about these predicates (cf., e.g. Talmy 1988) is that there is exactly enough force in an initial situation to maintain identity between it and the next situation, against a tendency otherwise.

We follow this intuition informally here, leaving detailed formal denotations and model-theoretic considerations for when we have developed a full semantic model (Copley & Harley, in prep.). Consider an initial situation *s* where *p* holds. If *s* is a *keeping* or *staying* situation, there is a subsituation *s'* identical to the initial situation in all respects except for the absence of the individuals and/or properties that generate the *keeping* or *staying* force. This “agonist” subsituation *s'* has a net force *f'* which, when opposed to the “antagonist” net force *f''* of the rest of *s* (i.e., the net force of *s* minus *s'*), results in a transition to a final situation of which $\sim p$ holds. The net force *f*₀ of *s*₀ is equal to *f'* + *f''*, and can be thought of as having magnitude zero (though strictly speaking magnitudes are not part of the framework). Thus, *keeping* and *staying* involve a net force of a situation *s*₀ of which a property *p* holds, and whose successor situation *s*₁ would, in the absence of the properties that give rise to the agonist component force *f'*, be a situation of which $\sim p$ holds. *Keep* and *stay* hence introduce predicates of forces with the special property that their initial and final situations are identical with respect to *p*, but which, without the input of the agonist component force, would differ with respect to *p*.

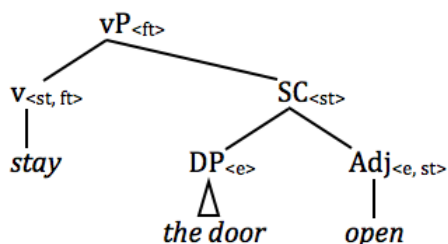
⁵⁹ In contrast, a stative predicate such as *The door (is) open* picks out situations to which no force need

⁵⁹ Note that the force in question, in for example *Mary is keeping the door closed*, could be a physical action on Mary’s part, or could reflect Mary’s opposition to the normal tendency for the door to be open (perhaps Mary likes to have her door open but exceptionally on this occasion she has a reason to have it closed.) The potential for such abstract forces is entirely in line with what we have said above concerning abstract tendencies in section 2.1 above.

be added in order for *p* to endure over time—that is, they describe a situation of which *p* is true, and whose successor situation also has the property *p*, *ceteris paribus*.⁶⁰

In the force-theoretic analysis, then, the predicates *keep* and *stay* are very similar to the predicates *open* (transitive) and *open* (intransitive) above, bearing the same relationship to each other that usual causative/inchoative pairs do (following Jackendoff 1975, among others). Let us consider *stay* first, as in *The door stayed open*. It will take a complement that is a predicate of situations, type $\langle s, t \rangle$, and require that this $\langle s, t \rangle$ complement be true of both the initial situation and the final situation. Note that the verb *stay* is base-generated here in the *v* head position, and that the present proposal thus treats it as a light verb; this is in keeping with many standard analyses (see e.g. Givón 2001:166, Levin and Rappaport Hovav 2008).

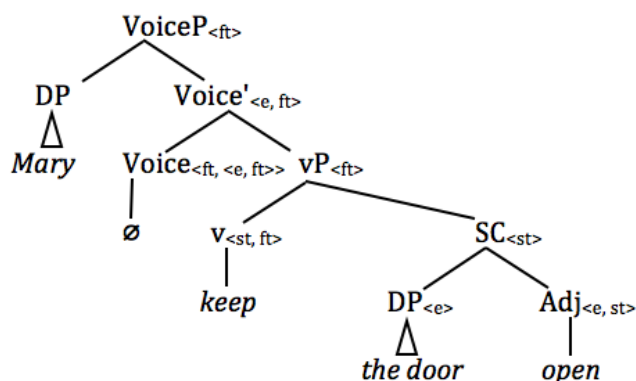
(71)



(72) $\llbracket v_{\text{STAY}} \rrbracket = \lambda p \lambda f . p(\text{init}(f)) \ \& \ p(\text{fin}(f))$

Keep and *stay* are then differentiated in the same way as our inchoative/causative pairs above, in that *keep* includes a VoiceP projection which introduces an external argument and asserts that it is the source of the force; and *stay* does not.⁶¹

(73)



We thus treat *keep* as a transitive suppletive variant of *stay*, in the same way that *raise* is

⁶⁰ See also van Lambalgen and Hamm (2005:42): "A property persists unless it is caused to change by an event."

⁶¹ We assume that when *keep* or *stay* takes an apparently eventive predicate as its complement, as in *John kept Bill running around all day*, the aspectual operator represented by *-ing* has applied to map the $\langle f, t \rangle$ constituent [run around all day] to an appropriate $\langle s, t \rangle$ predicate.

allomorphically related to *rise*, *lay* to *lie*, *teach* to *learn*, and *feed* to *eat*.⁶² Both *keep* and *stay* are dynamic predicates, but do not provoke a change. The initial situation s_0 has net force which creates a transition to s_1 but it is a zero magnitude net force and a trivial transition.

6. Concluding thoughts

We began the paper with a problem—how to account for the “*ceteris non paribus*” or “defeasible causation” cases in which the cause happens but the effect does not necessarily occur. We proposed a causal function from situations to situations, to allow reference to the effect without having to assert its existence, and we argued that this function corresponds nicely to the idea of *force*. The force argument replaces Davidson’s event argument in “eventive” (for us, “dynamic”) predicates.

With this model in mind, we turned to the syntax/semantics interface in order to clarify how the proposed semantics is implemented compositionally in the argument structure, retaining recent advances in the understanding of the substructure of dynamic predicates while accounting for other phenomena which have not previously been amenable to analysis within the event-based framework, including the dynamic/stative distinction and verbs of maintaining. In developing these proposals, an important advantage of the framework was its ability to make a natural type-theoretic distinction between dynamic and stative predicates: stative predicates are predicates of situations, while dynamic ones are predicates of forces.

We would like to conclude by pointing out several ways in which the force-theoretic framework provides more natural divisions of labor between linguistic semantics and other domains than previously possible, making the case that it represents an advance in carving the world more nearly at its joints.

The first such redivision of labor is entirely within the semantics: instead of event arguments and world arguments, the force-theoretic framework uses force arguments and situation arguments (the former effectively derived from the latter). As we have suggested, force and situation arguments share some of the work previously done by event arguments, since dynamic predicates are predicates of forces and stage-level stative predicates are predicates of events. However, in another sense, the force argument takes on some of the work previously done by world arguments, in handling the *ceteris non paribus* cases. One reason why such a redivision of labor may be advantageous is that it allows us to construct possible worlds out of causal chains of situations. It is worth considering whether possible worlds might be constructed using the very same elements used to build causal chains in the vP.⁶³

⁶² Our v_{STAY} is in effect a verb-of-maintaining version of our v_{BECOME} . It is interesting to consider the possibility that there might be verb-of-maintaining equivalents of our other little v heads v_{APPEAR} , v_{EMERGE} , and v_{OCCUR} . At first glance it looks like v_{APPEAR} has a verb-of-maintaining equivalent in *endure* (and its transitive counterparts *preserve* and *maintain*). We might expect a language with a morphologically overt v head to distinguish between regular and maintaining versions of v_{EMERGE} and v_{OCCUR} (which could be glossed perhaps as ‘persist’ and ‘continue’) but since in English the verbal root incorporates into the v , these would not be morphologically distinct from their non-maintaining counterparts in English; thus it is difficult to say whether there are maintaining equivalents of v_{EMERGE} and v_{OCCUR} . However, the morphological complexity of all these predicates may instead indicate that these should be analyzed with small clause complements, like verb-particle constructions (Marantz 2001). If that is the case, they would involve v_{STAY} composing with a small clause containing an existence predicate. This latter course may be indicated also because of the problem of ensuring identity between the entity in the initial and final situations, which in the non-maintaining versions are quantified separately. In fact, this issue of quantification may well be a justification for treating propositions differently from entities, as we did in footnote 44 above.

⁶³ See Cipria & Roberts, 2000, and Del Prete, 2012 for other accounts involving chains of situations extending into the

In contrasting the force-theoretic (world-constructing) and primitive-possible-world viewpoints, it is worth noting that the generation of all possible inertia worlds in the latter approach is not an entirely innocent move. There is an analogue of this operation in another corner of linguistic theory: Optimality Theory's GEN operation (Prince and Smolensky 1993/2004). What GEN does is to generate all the possible realizations of an underlying form. The move to Optimality Theory from rule-based derivations is motivated in large part by cases that seemingly cannot be derived by rules (functions) that map one form onto another in the course of the derivation. The analogy between rule-based derivation and force-theoretic construction of worlds should be clear. However, in the case of physical situations, our conceptual representation of the laws of nature take us from one situation to another. Since these laws determine the next situation that we predict, in the force-theoretic framework it is superfluous to posit the analogue of a GEN operation that requires us to weed this situation (or a set of such situations) out from among all the other possible situations or worlds. We recognize that where primitive possible-world theories shine is exactly in indeterministic cases where s_0 underdetermines what happens later or what is inferred: modals such as *might* or *may*, for instance. We have not dealt with these cases. In the lexical cases we have been considering, however, we find it significant that the question of underdetermination seems not to arise, and this is why we feel comfortable modeling these cases with our locally deterministic, globally indeterministic approach.

A second redivision of labor arises from the possibility for reference to one argument in terms of another, without the need to bind the argument existentially; instead it is introduced as the result of applying a function to an argument, whether that function is a force or another function such as *net*, *init*, or *pred*. Consequently, there is also no need to introduce each such argument via its own functional head. The semantics can refer internally to such substructure without imposing the need for a corresponding syntactic projection in each case, taking over some of the work done by individual argument-introducing predicates in syntactic approaches to event decomposition.

Finally, the force-theoretic framework invites a deeper investigation of the division of labor between cognition and the grammar. A mapping between linguistic semantics and cognition has always been necessary; often it is assumed to be trivial, though by no means always; the line of inquiry exemplified by Krifka (1998) for instance, goes into extensive detail on such a mapping. In the present proposal, because of the dual nature of forces as conceptual forces (perceived inputs of energy) and linguistic forces (functions from situations to situations), there must be a conceptual level ("Conceptual Form"?) that is rather distinct from the semantic level Logical Form. We are pursuing the possibility in other work (Copley & Harley, in preparation) that model-theoretic tools can be applied to elucidate the conceptual in the same way that they make possible an explicit evaluation of the linguistic semantic computation. If this can be done, there is the intriguing possibility of simplifying the semantics by recognizing that the relevant complexity resides in the conceptual system.

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