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 expression of causation in event semantics remains problematic. Firstly, the causal relation—represented as something like "$\exists e_1 \exists e_2 : e_1$ CAUSE e_2"— is typically introduced via brute force, often by an extra rule of composition devised specifically for the purpose. Second, the usual way in which causation is encoded is too strong. Statements like "$\exists e_1 \exists e_2 : e_1$ CAUSE e_2" entail the occurrence of e_2 because of the fact that e_2 is bound by an existential quantifier. However, this complicates the analysis of common "ceteris non paribus" cases in which causation is interrupted, i.e. where e_1 occurs but the expected e_2 does not. We address both of these problems, the first by introducing the causal relationship via Functional Application, and the second by encoding the defeasible nature of causation directly in the model. The core concept that we use in this reconceptualization of event semantics is 'force', an input of energy. 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.

In the first section we motivate our use of the concept of force as the answer to the theoretical and empirical problems with (neo-)Davidsonian event theory. We begin by reviewing the existing literature on sub-evental composition in Accomplishments, pointing out that strict compositionality is not always maintained in the literature, and that for some forms (e.g., the progressive and non-culminating accomplishments) the existential status of the caused sub-event is murkier than that of the causing sub-event; previous attempts to account for this either require additional machinery (possible worlds; e.g., Dowty, 1979) or fail to adequately address the issue (partial events; e.g., Parsons, 1990). We propose that defeasible causation should not be understood as a derived phenomenon, but rather as the basic one, presenting data from a range of languages in support. We argue that causation should be treated as a function from an initial situation to a final situation that occurs *ceteris paribus*. This causal function is identified with the naïve metaphysical notion of force, since unlike events, forces are naïvely understood to be inherently defeasible and to interact with each other in deterministic ways.

We take the Davidsonian argument in dynamic predicates, therefore, to refer to a force instead of an event. In the second section we further flesh out this proposal, introducing situations as "annotated snapshots" provided by the cognitive system, and treating forces as arising from the properties of entities in these situations and their interaction with what we call the 'normal field'. The normal field includes gravity and other tendencies, and produces forces just in case an individual with appropriate properties is present in the situation. A special case within the normal field covers individuals with intentions: the Law of Rational Action produces a force just in case an individual has a goal and nothing prevents that individual from acting to achieve it. To close out the section, we point out how the notion of "force" relates to the notion of "event," before providing our formal framework in section 3.

Section 4 explicates 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, proposing 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.

In section 5, 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.*

The final section concludes the paper; we situate the force-theoretic framework in the context of existing philosophical perspectives on causation (especially David Lewis's, which has been influential in formal linguistics), and we detail the positive aspects of several redivisions of labor that are entailed by the theory.

1. Motivating forces

We begin with a quick review of the role of event arguments in semantic theory, sketching the development of the event-chaining view of event types involving transitions, and presenting a theoretical difficulty encountered in the general framework. We argue that treating Davidsonian arguments as referring to forces, rather than to events, addresses these issues in a more satisfactory way.

1.1 A brief history of event arguments

The Davidsonian revolution in semantics reified the notion of 'event'. In his discussion of sentences like that in (1), Davidson (1967) proposed that there is something—an event—that the predicates *with a knife, in the kitchen,* and *at midnight* are all predicates of.

(1)   Brutus killed Caesar with a knife in the kitchen at midnight.

Davidson's claim was that events are as real as individuals in that they can be observed, they have spatial and temporal location, and they can be referred to with pronouns.

Neo-Davidsonian analysts saw a way to extend Davidson's proposal to characterize semantic subcomponents of predicates, such as theta roles. They proposed to extract core arguments from the main predicate and introduce them via two-place predicates such as Agent (x, e) and Theme(y, e). The main predicate is thus reduced to a one-place predicate of events, on a par with the event-modifying adjuncts in Davidson's schema (Castañeda 1967 et. seq.).

Kratzer (1994, 1996) presents a fully articulated version of this approach to the introduction of the Agent role. The syntactic verb phrase is divided into two constituents, a lower VP predicate of events which introduces both the verbal lexical semantic content and the internal argument, and an upper VoiceP, another predicate of events which ascribes Agentivity to the external argument. The two projections cannot combine via Functional Application, however, and Kratzer introduces a dedicated composition operation, Event Identification, to coindex the event variables of each subpredicate. Kratzer's use of an additional rule of composition reflects

the fact that the reification of events complicated the syntax/semantics interface; mechanisms for linking event arguments appearing in distinct structural locations were not available in existing formalisms.

Subsequent theoretical developments exacerbated this technical problem. A separate line of analysis investigating the internal structure of events produced a consensus that certain events—Vendlerian Accomplishments, most saliently—are in fact composed of two sub-events, chained together in a causal relationship: *John opened the door*, for example, has a causing sub-event e_1, and a result sub-event e_2 of the door being open. These theories allowed 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), Giorgi & Pianesi (2001), Kratzer (2004), Ramchand (2008), a.o.).

While these developments allowed for insightful analysis of the structural and semantic properties of complex events, the introduction of the 'chaining' relation posed its own challenges for the syntax/semantics interface. In the analytic tradition deriving from the work of Frege and Montague, the meaning of complex structures is expected to emerge straightforwardly from two factors: the denotations of the structure's parts and the way they are composed. The prototypical rule of composition is Functional Application:

(2)   Functional Application (Heim and Kratzer 1998)
       Where α is a node and β and γ are its daughters, $[\![\alpha]\!] = [\![\beta]\!] ([\![\gamma]\!])$
       The type of $[\![\beta]\!]$ is $<x,y>$, the type of $[\![\gamma]\!]$ is x, and the type of $[\![\alpha]\!]$ is y.

An important heuristic deriving from this tradition is that multiplication of composition operations is to be avoided. However, often the implementation of the event-chaining insight required the introduction of a novel rule of composition. And in fact, the idea of event-chaining raised a more foundational issue than Kratzer's event-identifying theory did. Instead of merely identifying different arguments with each other, which is at least a familiar syntactic issue, the sub-eventual analyses of accomplishments brought up the question of how to link the arguments in distinct positions into a *causal* chain.

In Pustejovsky's (1991: 41) treatment of accomplishment predicates, for example, "the operator *cause* can be seen as a derivative relation between events, structurally interpreted from an agentive predicate within the initial subevent of an event structure." That is, the denotation of the mother node is composed from the denotation of the daughter nodes by appeal to a special rule of composition introducing the causal relation, which applies when the structural description is met:[1]

(3)

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[1] For cases in which the result is introduced by a prepositional phrase, such as *Mary ran to the store,* Pustejovsky's proposal is that *ran* is type P (Process) and *to the store* is type <P, T> (where T stands for Transition), and the resulting denotation of the mother node is type T. So in such cases, something more like Functional Application is invoked. However, the presence of "cause" in the final denotation indicates that the compositional rule he has in mind is not Functional Application, but rather includes the information about the causal relationship between the process and the result.

a. John closed the door.
b.
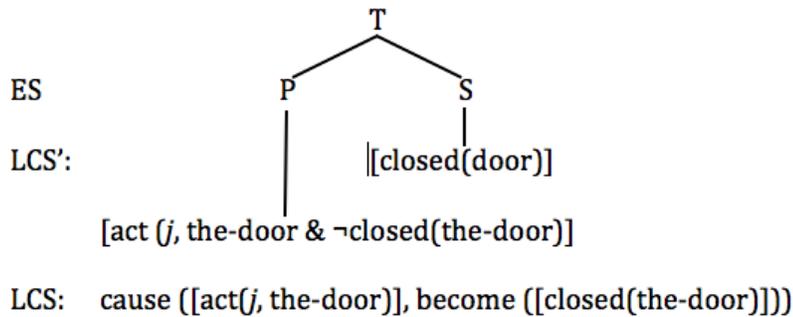
Higginbotham (1999:132), to take another example, proposed that the causal relation between the two subevents is "the result of a combinatorial operation . . . the combination of e and e' … project[s] as a telic pair." Higginbotham's rule of telic pair formation produces the following denotation for a change-of-state VP (Higginbotham 1999:137):

(4) $\exists e \exists e'$ [agent(John,e) & saddled(the horse,e') & (e,e') is a telic pair

Kratzer's (2005:197) version of this operation, 'Causative Shift', is given below:

(5)   Causative Shift
       $\lambda P_{st} \lambda e_s \lambda s_s$ [state(s) & event(e) & P(s) & CAUSE(s)(e)]

Is is possible to account for the causal relationship between subeventualities without an extra rule of composition? As Kratzer discusses, one alternative to a special composition rule is to instead posit a lexical head in the structure with the causal relation as part of its denotation. This approach is also adopted by Ramchand (2008), where the 'leads-to' relation is part of the denotation of various v° subheads in an articulated vP architecture, each connected to its own particular subevent, namely a 'Process' subevent, an 'Initiating' subevent, and a 'Result' subevent. Such an approach avoids the problem discussed above, as it allows all denotations to be computed via Functional Application (see Bruening, to appear, for an adaptation of Ramchand's approach in a VoiceP framework). However, as we will now see, there is an empirical problem, arising from the assertion of the existence of a causal relationship between two events (as in "$\exists e_1 \exists e_2 : e_1$ CAUSE e_2") that applies equally to both the compositional and lexical solutions.

1.2   *Ceteris non paribus:* When e_2 need not occur

Denotations including statements like "$\exists e_1 \exists e_2 : e_1$ CAUSE e_2" are intended to express a certain causal relation, one in which e_2 is a consequence of e_1: the occurrence of e_1 entails the occurrence of e_2, both being existentially bound. However, there are many cases in natural language where e_1 has a causal relation to e_2, but e_2 does not neccessarily occur.
       The most well-studied such effect is the so-called "imperfective paradox" in imperfectives and progressives (especially the English progressive; Dowty 1979, Parsons 1990, Landman 1992, Portner 1998 among many others). The imperfective paradox is not really a paradox, but rather a problem stemming from the interaction of telicity with a certain kind of theory of the progressive (Montague, 1970, Scott, 1970, Bennett & Partee 1972). In event-

theoretic terms, the assertion of an accomplishment predicate entails the causative relationship between its subeventualities e_1 and e_2, but in the progressive, e_2 can in fact fail to come about. For instance, in (6) below, e_1 is Mary's painting, and e_2 is the result state (in which the dresser is black). (6a) shows that in English the assertion of a perfective accomplishment entails that e_2 occurs. However, in (6b), it is perfectly possible to say that Mary was painting the dresser without entailing that the result state occurred:

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

Many of the theories of the progressive that have been proposed to account for the contrast in (6) fall into two major categories. The first category of theories involve quantification over a certain normal or "inertial" set of possible worlds or situations, so that e_1 causes e_2, but only in these worlds/situations; the actual world need not be in this set. Dowty (1977, 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 Landman 1992, Bonomi 1997, Portner 1998, Naumann & Piñon 1997, Abusch 1985, Szabo 2004, Engelberg 2001 for possible worlds, Cipria & Roberts 2000, Del Prete to appear, for possible situations.)

      The theories in the second category propose the existence of partial events: an event e can either hold without culminating (hence it is partial) or it can culminate (especially Parsons 1990, but also Vlach 1981, ter Meulen 1985, Bach 1986, Kearns 1991, Krifka 1991, Landman 1992,[2] Smith 1997). To put this idea in event-chaining terms, we might say that an event e_1 can fail to culminate, i.e., cause e_2, simply because of being a partial event, though it would normally be expected to culminate in e_2. 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). The event-chaining machinery, as long as it existentially binds e_2, cannot handle the possible non-occurrence of e_2 in the progressive without either adding the technical apparatus of possible worlds, or leaving e_2 out entirely by appealing to partial events.[3]

      So-called 'non-culminating accomplishments' pose a very similar problem.[4] 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 (6a) above, for instance, is acceptable. 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 the resultant form does not entail the result of the caused event—the result is implied, but defeasible, as described by Travis (2000), and illustrated in (7) below.[5]

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[2] As Portner (1998) points out, Landman's theory falls into both categories.

[3] A third kind of approach, represented by Asher, 1992 and Glasbey 1996 is to take the requirement of normality to apply to inferences that speakers and hearers make about utterances. We will have more to say about this approach in section 1.4 below.

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

[5] 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.

(7) namory   ny ankizy   ny mpampianatra
     pst.*Agent*.meet   the children   the teachers

     ...nefa   tsy   nanana   fotoana   izy.
     ...but   neg   pst.have   time   they.
     "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.[6]

(8) 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.

(9) 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 mulitplied further, but we will just provide one final one here. Karachay-Balkar, a Turkic language spoken in Russia, also has non-culminating accomplishments (Tatevosov 2007):

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[6] 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 explictly 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).

(10) Kerim   ešik-ni   ac-xan-dɨ,   alaj   boša-ma-ʁan-dɨ.
      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.'   (Tatevosov 2007: 3)

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.[7]

The failure to entail culmination—that is, the defeasibility of the result e_2—might tempt one to wonder whether these cases are themselves some form of progressive or imperfective. For each of the cases above, researchers have gone to some lengths to demonstrate that they are not. For the Salish cases, for example, Matthewson 2004 shows that these forms do not behave in discourse as though they were derived statives (i.e., they advance the reference time), and cannot be an answer to the question "What is/was happening?". Bar-El et al. 2005 assert that the neutral form is perfective, lacking an overt marking for imperfectivity. And in Dell's (1987) Tagalog example in (8), 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.

Just as in a progressive, however, in all of these non-culminating accomplishments the agent does something—e_1 occurs—but can still be unsuccessful in getting the intended result to *happen; e_2 is defeasible*, i.e. not entailed. Not surprisingly, analyses of these facts have appealed to the same technology as analyses of the progressive: possible worlds (Matthewson, 2004, Tatevosov, 2007) and a theory (Singh 1998) of partial and complete agent roles that is derived from Krifka's (1991) partial and complete events. Dell's (1987) description of Tagalog neutral verbs as denoting a "maneuver" to achieve a "result" is an exception, falling into neither category, and is very much along the lines of what we will propose.

1.3 Defeasible causation as a function

Two problems arise, then, in the standard sub-eventual approach to causation: causally chaining events without formal stipulation is difficult, and the entailments of the CAUSE statement are too strong. We address both these problems by removing the CAUSE relation from the denotations and replacing it with an inherently defeasible formulation of the causal relationship.

The approaches to causation described above require a statement to the effect of "$\exists e_1 \exists e_2$: e_1 CAUSE e_2" somewhere in the denotation of the sentence, with both e_1 and e_2 bound by existential quantifiers. But the problem of defeasibility arises exactly in this existential quantification of the second event variable: the status of the existence of e_1 is treated in precisely the same way as the status of the existence of e_2. The additional machinery for treating the cases in which e_2 does not actually occur is needed in order to make sense of the different existential status of e_2.

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[7]The last as cited in Koenig and Cheif 2007.

Is there a simple alternative to treating CAUSE as a relation with existentially bound relata? Yes: we can treat the causal link as 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 partial events in the progressive literature. The initial argument is bound existentially. The output argument is defined by means of the function applying to the input argument, and can therefore be referred to. However, the fact that the output argument is defined does not entail that it actually occurs.

Treating the causal link as a function, then, allows for the output argument (i.e., e_2) to be referred to without entailing its existence. 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:

(11) $f_{CAUSAL}(e_1) = e_2$

This move could accommodate the cases of non-occurrence of e_2 that we address above within a traditional view of event-chaining. However, it should be noted that such an account would be successful only to the extent that f_{CAUSAL} could be defined at all. It is not trivial to ensure that there is a unique result e_2 of a given e_1, as the extensive literature on the progressive has shown us; in fact, as we will see below, it is not immediately clear that having a unique result event is even desirable. Of course possible worlds or partial events could be recruited to define f_{CAUSAL}, but then we are back to the same problem as before of extra machinery.

In what follows, we develop an account in which the input and output arguments of the causal function are situations (in a sense we will make precise). 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 causal function itself will turn out to take the place of the event argument for dynamic eventualities. We show that the ingredients needed to characterize this function can actually play a larger explanatory role in the semantics than an event-chaining treatment allows.

1.4 What is needed to get a unique output: a little perspective

As we have just seen, a causal function could solve the technical problem of the existential status of e_2. However, to define such a function over events, it must be the case that any particular event e_1 has a unique result e_2. This is intuitively implausible; Mary's leaving can simultaneously have many resulting eventualities: she is in a different place, Sue is upset, Bob calls Kim, etc. The effects of any given event are more widespread and amorphous than a function-based approach to causation would seem to allow. We seemingly cannot characterize a unique output for e_1 if the output has to be an eventuality. We will call this the 'multiple effects problem.'

This problem of the uniqueness of results is related to the "perspective problem," which is discussed at length in the literature on the progressive. The perspective problem goes like this: Suppose that Mary was in a plane whose pilots intended it to go to Tucson. On the way, the plane is hijacked, and it eventually ends up landing in San Francisco. As Landman (1992) a.o. points out, both (12a) and (12b) can later be truthfully asserted of a time after takeoff and before the hijacking.

(12) a Mary was flying to Tucson.
      b Mary was flying to San Francisco.

So it seems that e_1 (the flight) can be described as having two different e_2 results: one in which Mary is in Tucson, and one in which Mary is in San Francisco. The perspective problem is similar to the multiple effects problem in that they both involve multiple results of a single e_1; the perspective problem, however, is about potential, mutually exclusive results and the choice of lexical description of the e_1-e_2 chain, while the multiple effects problem is about multiple actual results.

 As has been pointed out extensively in the literature on the progressive, following Landman (1992), it seems that the speakers in (12a) and (12b) start from different assumptions about what is relevant to the evolution of the event. If the speaker takes into account only the pilots' plans and their ability (in the absence of the hijackers) to fly the plane to Tucson, (12a) is true. If, however, the speaker takes into account the hijackers' plans and abilities as well,[8] (12b) is true. The fact that both can be asserted indicates, it has been claimed, that the speaker is making a judgment about which individuals and which of their properties (e.g., their plans, their abilities) are relevant.

 What is needed, then, is some way to represent the speaker's choice of certain individuals and properties to consider from amongst all the individuals and properties that might be available. The notion of 'anchor situation' plays exactly this role in Krazter's (2011) recent theory of modals. Even more germane to the present discussion, in his analysis of the English progressive, Asher (1992) characterizes a 'perspective' as a "subset of information about a state." For Asher, the inference from $Prog(\varphi)$ to φ is defeasibly valid; it can, in particular, be defeated by the inclusion of additional information from the speaker's perspective. For example, (12a) is true by virtue of knowledge about what the pilots' intentions and abilities are likely to be, while if the hijackers' intentions and abilities are included as well, it is false. $Prog(\varphi)$ is taken to hold of a state just in case there is at least one perspective such that the state would or should lead to φ in the 'normal course of events', although there may be reasons why φ does not occur.[9]

 This view of the perspective problem might be expected to help us with the problem of the uniqueness of resulting events, provided that we could be sure that for each perspective, there was a unique conclusion about what was going to happen. However, this is not possible, as Asher points out. If, for instance, there is no generic statement in the speaker's perspective bearing on whether the hijackers are likely to succeed, then at a time when the plane has been hijacked but hasn't landed yet, it is impossible to commit to an inference as to whether the plane will land in Tucson or San Francisco. And in fact, both (12a) and (12b) can be asserted in such a case. So it certainly seems as though there are two e_2 results to a single e_1.

 Is this kind of example a reason to give up our quest for a unique outcome of causation? We think not. Recall that our quest came about from the independent conclusion that causation should be treated as a function. If we are prepared to posit that there is a unique outcome of a

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[8] The distinction is not an intensional/extensional as Engleberg (2001) claims; the very same argument could still be had when the plane hasn't landed anywhere yet.

[9] This same intuition is noted in by Dell (1987) in his discussion of non-culminating accomplishments in Tagalog: "We never have total control over the result of our actions. *The nature of [the] result always depends on circumstances which we cannot assess with any absolute certainty...*In the [neutral form], the emphasis is laid on the fact that the result came about only because the agent deliberately *initiated a causal chain which he had reasons to think would bring it about*," emphasis ours.

causal function, what we mean is that whatever happens, it will be unique. That is, the plane will go to only San Francisco or Tucson; it can't do both. This metaphysical uniqueness is therefore reasonable even for the perspective problem. The source of the two possible descriptions, then, must come from somewhere else. Using the idea of situations, it is perfectly possible to locate the perspective problem in the epistemology, as Asher does.[10] Given the speaker's understanding (choice of initial situation), it makes sense to say that the causal outcome of one situation is distinct from the causal outcome of a different situation; a speaker's knowledge of what is going on is typically incomplete. Consequently, the two descriptions of the flying event's outcome are based on two different understandings of the situation. A given speaker's understanding of the situation will include whatever individuals and properties are, in their estimation, needed to accurately model the eventual actual evolution of events. We will say that speakers choose a situation that is large enough to be, in their estimation, *efficacious.*

So, we can account for the defeasibility of the causal function by positing the possibility of different initial situations, much as Asher does. That is to say, the input argument of the causal function has to be a situation, not an event.

In fact, the output argument of the causal function has to be a situation as well. The reason for this is multiple effects problem, mentioned above: the fact that Mary's leaving (e.g.) can have many different effects--metaphysically, not epistemologically. Essentially, there is a situation s_0 in which Mary leaves, giving rise to another situation s_1, which has certain properties. If the result of Mary leaving is a situation s_1 with a number of different characteristics, we have a unique result of which a number of things can nonetheless be true.[11]

1.5 Functions from situations to situations: Forces

So far we have determined that the appropriate characterization of the causal function is as a function from situations to situations. So we would like to write the following:

(13) $f_{CAUSAL}(s_0) = s_1$

Note that the intuition behind this formulation of the causal link is not exactly analogous to the event-based version in (11) above. The reason is that the initial situation needs to do the job of the perspective; the state of affairs from which the speaker judges that the subsequent situation will follow if everything proceeds normally and nothing external intervenes—that is, the situation that will follow *ceteris paribus,* "things being equal". This is not the event referred to in the VP but (following Asher) it is the entire initial situation s_0 of which the whole progressive statement is true, including all relevant entities and their relevant properties. Similarly, the subsequent situation may include all sorts of entities and properties, but at a minimum, the result property holds of s_1. It will be a unique situation in which the result property holds, but the result property need not be the only property of that situation.

On this view of the causal relation, e_1 seems to have disappeared from the calculus. What, then, is actually taking us from the initial to the final situation? Formally, it is the causal function

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[10] We think Asher's states are more like belief states with information that causes updates; ours is a metaphysical analogue to what he is doing. and provides a syntax-semantics interface. but his should be useful for things that really may involve inference, i.e. epistemic modality and evidentiality.

[11] Both Asher 1992 and Kratzer 2011 use possible worlds; situations are treated as partial worlds. We will end up treating situations as semantic primitives and constructing possible worlds out of them.

that plays this role. We must therefore consider the possibility that the causal function in fact refers to e1.

There is a line of thought, associated in large part with a tradition in computer science, that treats events themselves as causal transitions between static representations of situations, as in motion pictures or comic books (Moens and Steedman 1988, Naumann 2001, Fernando 2005, ter Meulen 1990). Dahl 2007 also views events as transitions from one static situation to another.[12] Treating the event itself as the referent of the function from situations to situations[13] would solve the mystery of the missing e_1. However, the adoption of the idea of events as transitions does not on its own solve the "*ceteris non paribus*" cases of non-culmination discussed above. Although treating the event as the referent of the causal function seems to be correct, as we have seen, the causal link has to be defeasible, subject to unexpected intervening circumstances.

The notion of intervention seems to be key to understanding defeasibility. 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 something external interacts with something internal. This distinction can be modeled quite easily by exploiting the speaker's judgment as to what goes into the initial situation. What is so far missing is a clear notion of just how something external to the initial situation can intervene to perturb the trajectory of the transition. Many discussions of this kind of perturbation appeal to the concept of transmission of energy. Indeed, although it has not often been formally implemented (with the work of van Lambalgen & Hamm (2003, 2005) representing an important exception), the notion of energy has always been understood to be fundamental to the relationship between states, events, and transitions from one to another: [14]

> "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)

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[12] In a related vein, 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] The idea that events are transitions is in principle compatible with either relational or functional cause. There is also no reason to think that Davidsonian reference cannot be made to functions; note that the same issue arises for propositions or facts if they are thought of as functions of some kind (e.g., Stalnaker 1978), since, like events, they can also arguably be referred to by demonstratives, e.g. *It is not true*.

[14] In related discussion, Bohnemeyer and Swift (2006) characterize the defining quality of dynamic predicates as involving 'change' rather than energy or force, although they do ascribe force-dynamic semantic content to the English progressive for certain 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 below.

There is a perfectly natural way to talk about a (potentially perturbing) input of energy; it's a *force*. Like the idea of energy, the idea of force is well represented as an intuition even where it has not been explicitly implemented. Consider the following characterizations of intervention drawn from the progressive literature: "[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)[15]

What is it about the concept of force that suits it to play this role in the representation of causation? Intuitively, forces arise from objects and their properties, which are the components of situations. Forces transform objects and 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 cumulative effect (*ceteris paribus)* will be to lead to the subsequent state of affairs. Furthermore, forces can be opposed. A force which is countered by a stronger force will not produce the same result it would have in the absence of that stronger force. That is, the idea of force provides a natural understanding of how intervention can happen, as observed in the quotes above.

In the cognitive linguistic tradition, forces have been seen to be at the core of verbal meanings. Talmy (1976, 1981, 1985, 1988, 2000) has argued that the notion of force is relevant in linguistic semantics, starting from the common-sense insight that many lexical distinctions (*help, prevent,* etc.) are easily characterized in terms of force-dynamic interactions. Talmy's insight has been explored at length by others. Croft 1998:83-3 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)

Work by Wolff and others (Wolff & Song, 2003, Wolff 2007, Wolff, Barbey, & Hausknecht, 2010, Wolff, Hausknecht, & Holmes, 2010, Wolff, to appear) have extensively demonstrated the psychological validity of these proposals using experimental methods.[16]

Talmy (also Sweetser 1982, 1984) further proposed that the physical-force model maps straightforwardly to the psychological realm, since these same predicates are used to characterize psychosocial as well as physical causal relations. This proposal develops a central theme of cognitive linguistics according to which abstract conceptual content is derived from representations of physical reality (see, e.g., Bloom, Peterson and Garrett (1999) for an overview). In his work cited just above, Wolff has shown experimentally that the magnitudes and interaction of physical forces in a virtual environment can be very precisely predictive of

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[15] Landman does not in fact use the word "force" in his 1992 article.

[16] 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.

speakers' choice of lexical items for such predicates, and that the effects transfer unproblematically to psychosocial contexts.

Despite the ubiquity of the concept of 'force' in cognitive linguistic approaches and its usefulness in psychological investigations of causation, the only formalist approach to systematically employ the concept of 'force' that we are aware of is extensive 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 and should be treated directly in the model; for van Lambalgen and Hamm, this means writing it into the axioms of their formal system, p. 45; for us it is part of the the cognitive model. Another shared idea 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)

However, when van Lambalgen and Hamm introduce forces, it is as a supplement to the familiar machinery of events, processes and results, in contrast to our framework, which—similarly to the cognitive linguistics viewpoint— views forces as irreducibly central to the cognitive and grammatical representation of dynamic verbal predicates. 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.

We should also point out that, in contrast to both the cognitive tradition[17] 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 advances made in the understanding of the syntax-semantics interface. With a view towards this goal, we implement the notion of force in the next section.

2.0 Situations, forces, events and states

We have argued above that the right way to understand dynamic events is to treat them as forces: that is, inputs of energy into situations. Such inputs of energy can but need not have an effect on the state of affairs; this inherent defeasibility provides the tools necessary to naturally accommodate the problems raised above.

We have seen two kinds of data—progressives and non-culminating accomplishments— whose key similarity lies in the fact that the predicate, which encodes a specification of its end result, can be asserted even in cases where the end result never obtains. We turn now to the task

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[17]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.

of defining a force-based semantic model that gives us a new insight into the nature of this specification of the end result. We build defeasibility into the representations by treating a force as a function from a situation to its *ceteris paribus* resulting situation.

In section 2.1 and 2.2. we begin with an investigation of our basic notions of "situation", and "force", discussing how something like gravity might be represented and what such a representation has to do with a more abstract, non-spatiotemporal notion of force. We give a brief account of how psychological forces such as intentions are to be understood. followed by a comparison of these concepts with the notions "event" and "state" in section 2.3.

2.1 Situations

So far we have characterized a force as an input of energy into some initial situation. We rely on the very basic intuition that a situation is a spatiotemporal arrangement of individuals represented together with (some of) their properties.[18] We assume that the cognitive apparatus is equipped to construct such representations, which are thus supplied to, rather than constructed by, the linguistic computational system. This view of situations thus constitutes a position on a debate within the Situation Semantics framework as to the linguistic or non-linguistic nature of situations (Barwise 1981, Barwise and Perry 1983, Kratzer 1989, Ginzburg & Sag 2000, a.o.; see Kratzer, 2011, for an overview). If a situation (like a possible world) is defined with respect to propositions that are true of it, it is clearly a linguistic object. The idea of situations as informational is closer to what we are proposing. For us the linguistic system can access a conceptual representation of s and appeal to that conceptual system to decide whether p(s) is true or not, but s itself is not defined with respect to which propositions p are true of it; as far as the linguistic system is concerned, s is primitive; we do not treat situations as partial worlds.

We insist on a cognitive characterization of situations because of the use to which we will put them in generating forces. Remember, forces arise from situations by virtue of the individuals and properties in the situation. It would be a mistake to say that forces arise from a set of propositions. But that is exactly what we would have to say if we took on a Situation Semantics definition of situations. In this respect, we are taking a stand on the need for a distinction between naïve metaphysics and epistemology; our situations are firmly in the realm of metaphysics. We have no problem with sets of propositions being used as part of a strategy to represent beliefs about situations, but in that case the correlated notion of a function from one belief state to another really must be that of information or inference that brings about a new belief state. In fact this *modus operandi* is a key insight behind the Dynamic Semantics/File Change Semantics/Discourse Representation Theory tradition (Kamp 1981, Heim 1983, Kamp and Reyle 1993, and many others since then).

Our notion of situation is quite close to Gärdenfors' (2005, e.g.) "conceptual spaces" (which replace possible worlds) and really not far from the notion of a Discourse Representation Structure in DRT; we are, for instance, especially appreciative of the discussion in Hamm, Kamp, & van Lambalgen 2006 on how Discourse Representations Structures are to be understood as mental representations. Where we part company with them is with respect to their idea that relationships between these representations are exhaustively determined by inference principles and entailment relations between propositional elements in said representations. We submit that in treating our situations as metaphysical rather than epistemic objects—as we must

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[18] Thanks to Laurent Roussarie for inspiring us us to clarify our thoughts on the nature of situations.

if we agree that in referring to a situation we are at least intending to refer to the "real world" instead of to our belief state—we are precluded from constructing them out of propositions and relating them to each other by propositional means. This means that if there is a "belief" evoked to characterize our cognitive relationship to these situations, whatever it is, it is not a linguistic belief; perhaps it is "nonconceptual content" in the sense of the proposals of Bermúdez (1994, 1998) and Peacocke (2002).

Our situations bear more than a passing resemblance as well to approaches in computational linguistics and computer science in which "snapshots" are appealed to (e.g. Moens and Steedman 1988, Naumann 2001, Fernando 2004). We have nonetheless called them 'situations' here because we recognize that the notion of 'situation' in Situation Semantics plays a very similar role (as in, for instance, the discussion above of the perspective problem, where Kratzer's and Asher's Situation Semantics accounts were relevant); we anticipate that the notions will in many cases map relatively straightforwardly onto each other.

As Klein (1994) argues, situations are what speakers talk about. In making a decision to talk about the world, a speaker chooses a subpart of all the available entities, properties and spatiotemporal locations as the domain under discussion. The question then arises as to how this subpart is chosen. The speaker, as we have seen, takes a perspective in choosing this domain. The choice reflects a speaker's best guess about what justifies the content of their sentence; it includes the entities and properties referred to in the utterance, as well as other entities and/or properties of entities that, as we have seen above, have been termed *relevant.* In the current framework, relevance is determined by the speaker's expectations about interaction: the chosen initial situation reflects the speaker's idea about which entities and properties do or will interact to result in whatever will (or won't) happen next, whereas irrelevant entities and properties are those which are expected to have no interaction with the topic situation. As we have said above, a speaker must choose what is in their view an *efficacious* situation.

2.2 Forces

Having presented our concept of situation above, we next turn to our conception of force. First we address the relationship between situations and forces, explicating our claims that forces both arise from and apply to situations; the cognitive system evaluates the interaction of component forces to calculate a net force for any situation it represents. We assume that some forces arise straightforwardly via the generation of kinetic energy from properties of physical objects like motion and mass; however, there are a number of more abstract cases that require further attention. In the remainder of the section, we discuss such abstract cases, and then show how forces (both concrete and abstract) can arise from the interaction of properties of individuals with a force-generating field: We consider in turn forces arising from gravity and other 'tendencies,' and forces generated by an individual's intention.

2.2.1 Calculating a force from a situation

A force, we have said, arises from the individuals and properties that comprise an initial situation.[19] The most prototypical forces may well be those generated from an individual's kinetic energy (derived from its mass and motion), as in, for instance, the free-body diagrams

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[19] On the other hand, not all functions from situations to situations characterize forces.

familiar to anyone who has taken an introductory course in physics or played billiards. When an individual's property has a leading role in generating a force, we will say that the individual is the *source* of the force.[20] For the moment we will keep such simple physical interactions in mind, then generalize to more abstract cases.

We assume that the cognitive system sums the forces acting in a 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, similar to that in a free-body diagram. The product of the summation is a force which produces the single situation that happens next. We will call this the 'net force' of the initial 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.

In our understanding of force, then, the initial situation plays two crucial roles. On the one hand, the cognitive system inspects the initial situation to calculate its net force, a process which does not occur internally to the grammar. On the other hand, the initial situation is also used by the grammar: the semantics takes the net force given it by the cognitive system, derives from it a function from situations to situations, and applies this function to the initial situation, thereby introducing the final situation into the semantic computation. The final situation thus introduced is the situation whose properties and individuals are the *ceteris paribus* outcome of the net force generated from and applied to the initial situation. It is worth noting that this situation itself will have a net force, which may, *ceteris paribus,* lead to another situation; things keep happening via such causal chains of situations.

In the formal framework we propose below, the grammar refers to the net force of a situation, but not to any component forces which may have gone into its calculation in the cognitive system. However, such component forces of the situation's net force can straightforwardly be represented as net forces of subsituations. That is, any force can in principle be represented by the grammar as a function, given the appropriate initial situation,[21] and lexical items describing net forces can be sensitive to the direction and relative magnitude of the component forces which make it up, treated as net forces of well-defined subsituations. This accommodates Talmy's (1988, 2000) insight that component forces are referred to in the meanings of agonist-antagonist lexical items such as *enable, prevent,* and the like. In such cases, a subsituation s' is considered which consists of the initial situation minus the agonist. For *enable,* the agonist generates a force whose direction is the same as the net force of s' without the agonist present; *prevent* is similar but the component force generated by the agonist is instead opposed to the net force of s'.

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[20] We discuss the notion of 'source' further in section 4.4 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.

[21] We hypothesize that certain subsituations are unlikely to be chosen as initial situations for the purpose of language; this hypothesis suggests the need for a multi-pronged investigation into how initial situations are chosen. Some subsituations are, we imagine, difficult for the cognitive system to isolate (e.g. the situation whose net force is the gravitational force generated by half of a planet); others might be precluded by the linguistic computational system in certain structures; and still others might be unacceptable for pragmatic reasons. As we have said above, one possible constraint on speaker choice of initial situation is that it be efficacious.

We suggested above that the prototypical cases of physical forces are forces arising from kinetic energy that, *ceteris paribus,* produce motion of an object so that its position changes from one location to another (think billiard balls). But actually, *any* change could be represented as motion from one state of affairs to another. This kind of abstraction from motion to other kinds of change is already present in Aristotle's *Physics* (V.2):[22]

> ...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....

It is also pervasive in the lexical semantic, cognitive linguistic and formal literatures on events (see, among very many others, Levin & Rappoport Hovav 2008, Jackendoff 1975, 1991, Talmy 2000, Croft 1991, Ramchand 1997, 2008, Kennedy & Levin 2008, etc.)

In our model, forces (inputs of energy) are what produce change. We therefore conclude that forces are appropriate to model predicates denoting any of these types 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. The cognitive apparatus's force summation calculation for a situation is thus massively multidimensional, including forces acting in directions other than the purely spatial. It is this multidimensionality which precludes (and subsumes) a treatment of forces as "acting on" objects. Although forces that "act on" a number of different objects in a situation cannot be summed together in a free-body diagram, we claim that they *are* summed by the cognitive system in calculating the trajectory to the result situation.

2.2.2 Gravity, tendencies, and the normal field

We have said that forces arise from objects and their properties. There are certain forces whose existence depends on a third factor, so far unmentioned. If someone pushes on a cup as it is sitting on a table, it is evident that there is an application of energy. But if you hold a cup in the air and then let go of it, and it falls due to gravity, where is the "application of energy"? There are two answers to this question: the ancient physics answer (represented here by Aristotle) and the modern physics answer. Both answers will be useful to us in their own way.

The Aristotelian explanation (*Physics*, VIII:4) is that heavy things (earth, etc.) have a tendency to descend, while light things (smoke, fire) have a tendency to ascend:

> "[H]ow can we account for the motion of light things and heavy things to their proper situations? The reason for it is that they have a natural tendency respectively towards a certain position: and this constitutes the essence of lightness and heaviness, the former being determined by an upward, the latter by a downward, tendency."

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[22] 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.

In Talmy's work (1988, 2000, e.g.) on the linguistic reflexes of cognitive representations, he echoes this Aristotelian notion:

> "…in terms of the cognitive structure of language, an object in a given situation is conceptualized as having an intrinsic force tendency, either toward action or toward rest. This concept appears to correlate with historically earlier scientific theories involving an object's impetus in motion or a tendency to come to rest" (Talmy 2000 (1): 456).[23]

The modern understanding of gravity (setting aside quantum mechanics) is that of a vector field that interacts with objects in it.[24] Any object with mass in a gravitational field has a gravitational force on it that is calculated by using both the value of the vector field at the location where the object is, and the mass of the object. The "application of energy" comes from the potential energy stored up by the energy it took to put the object at that location in the field. So, it takes energy to raise the cup to the table, against the force of gravity. This energy is converted to acceleration if the cup should fall.

These two viewpoints both express the idea that where there is gravity and an object with mass, a force arises; as usual, this force results in an event if nothing stronger intervenes. In both viewpoints there is an expression of the general (the tendency itself, or the ability of the field to exert a force on any object put into it) and the particular (the specific force that arises from the tendency in any particular situation, or the force that arises from the field acting on the particular object).[25] A tendency or field, whatever its provenance, is therefore treated in any particular scenario as producing a force, which is included in the summation that yields the net force. Like any other force, this force has defeasible effects; for instance, if a table is supporting a cup, the cup will not fall, despite the action of the force that is generated by the interaction of the cup's mass with the earth's gravitational field.

In our formal treatment below of propensities like gravity, we will exploit the idea of a vector field. However, the notion of gravity as a tendency has its usefulness too, particularly because it underlines the conceptual similarities between gravity and other tendencies. Consider, for example, a fruit ripening: the initial situation includes the unripe fruit and the successor situation includes the ripe fruit. Like other forces, this ripening force has a defeasible effect; the fruit ripens unless it is chilled, eaten while it is still green, etc. Insofar as ripening very generally happens to all objects that are fruit, have a certain temperature and are in otherwise appropriate physical scenarios, this case is less like pushing a cup and more like gravity: fruit has a tendency to ripen, just as objects have a tendency to fall. This would entail that even when the fruit is in

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[23] Newtonian physics has done away with this idea of tendency to natural place but has its own tendency, namely *inertia*. Beginning with Newton, rest is simply zero velocity, and objects tend to move at their current velocity unless acted upon by an outside force (the First Law of Motion).

[24] In physics, forces are represented as vectors. Vectors are determined by three parameters, namely, an origin, a direction, and a magnitude. For our purposes, the origin (or source) will usually be the agent or causer. The direction is, in an abstract sense, towards the force's *ceteris paribus* final situation. Magnitude is only important in relative terms, to characterize the interaction of opposing forces. We will not have much further to say about the vector representation of forces, although we will exploit intuitions deriving from such representations in illustrating causal chains of forces below.

[25] Note that although in everyday speech we talk about the 'force of gravity', this is not how 'force' is used throughout this paper. The 'force of gravity' is in fact a gravitational field, not a force. The word 'force' in this paper is typically picking out a force token, a particular force in a particular situation.

the refrigerator and is not undergoing the change normally provoked by the ripening force, there is still a ripening force on it; the *ceteris paribus* effect of this force has however been defeated (at least until the fruit is taken out of the refrigerator).

To summarize, we model tendencies by appealing to two principles: defeasibility of the force generated by the tendency (defeasibility being inherent to any force, as we have proposed), as well as ubiquity of the force within a certain domain, i.e., the force is generated whenever an object has the relevant properties.[26] Our proposal here is to treat these as more abstract analogues of the case of gravity.

To implement this parallel between gravity and other tendencies, we will make use of the more modern idea about gravity: we propose to collect tendencies such as that of objects to fall and that of fruit to ripen into something we will call the "normal field," imagined as a vector field (a formal object that takes objects and returns an appropriate force just in case the object has the right properties). We will thus talk about "tendencies" as being part of the "normal field" (though we could equally talk about the tendencies themselves as "fields"). Just as we have said for tendencies, in order for a field to give rise to a force, there must be an object with the appropriate properties. So the normal field can include the tendency of fruit to ripen, for instance, but unless there is a fruit in the initial situation, such a ripening force is not realized. This means that all tendencies can be included in a single normal field.[27]

The forces generated by the normal field are considered together with any other forces present in the situation, and the cognitive system calculates the net force of the situation—the one that will lead to the *ceteris paribus* successor situation, if nothing external intervenes.

Now that we have a way to think about normality, let us take a moment to deconstruct the *ceteris paribus* clause, our notion of 'all else being equal'. Normality is key in treatments of the perspective problem elsewhere in the literature, and the perspective problem was part of our motivation for *ceteris paribus* above in section 1.4: it gives us a way to think about non-intervention, and what it means for something external to intervene. However, we have now introduced the normal field, and normality certainly seems to have something to do with "all being equal". Let us be precise about the contribution of each of these constructs to what it means for all things to be equal.

We assume that the speaker's perspective includes the choice of the initial situation as well as a specification of the (relevant parts of the) normal field. The initial situation has individuals and properties in it.[28] The speaker represents certain forces that exist due to the

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[26] It has been a problem, especially with generics (e.g., *Dogs have four legs)* to understand how general tendencies can have exceptions; though we don't provide a formal treatment of generics here, we note that Eckardt (2000) has already argued convincingly that universal quantification can be maintained in generics if the quantification is over only normal worlds; exceptions occur in the non-normal worlds. For us, defeasibility of the force generated by the interaction of the tendency and the individual yields normality in a similar way; the force leads, *ceteris paribus,* to a defined resulting situation, but sometimes *ceteris* is not *paribus*, hence, exceptionality, even though the force generated by the tendency always applies as long as the object has the relevant properties. Stereotypical ordering sources for modals (Kratzer 1981, 1991, Portner 1998) also call on "what is normal".

[27] It is clear that the normal field should be relativized to time, the speaker, etc. Since for the data we are considering in this paper, the normal field does not make an appearance in the semantics, we will not worry about this relativization here.

[28] We allow that some of the properties of individuals the speaker considers may well be due to normal or default inferences made by the speaker. As we noted above in section 2.1, we think that such beliefs can be non-linguistic (i.e., non-propositional), but to the extent that linguistic (propositional) beliefs might be involved, we would assume that there is an analogous normal field in the informational/epistemic domain, similar to work by Asher (1992, e.g.) in which belief states are populated with additional inferences: the tendencies in this informational normal field all

interaction of the individuals and his conception of the normal field. He also represents forces particular to the situation itself. The summation of all such forces, both those arising from the normal field and those particular to the situation, produces the net force of the situation. This net force will result in the successor situation provided that nothing external to the initial situation intervenes. In this way, the speaker creates his own metaphysical model, a causal chain of one situation following another according to his choice of initial situation and the situations he judges will follow.

Ceteris paribus, then, encompasses two separate ideas about the 'normal' evolution of situations: First, that the normal field applies, and second, that nothing external to the initial situation intervenes. We will continue to talk about a net force leading to another situation "*ceteris paribus*" but both facets should be borne in mind: when all else is equal, the normal field is involved in the calculation of the net force, and nothing external to the initial situation intervenes. Thus, when *ceteris* is not *paribus*, things can go wrong in two ways: an outside force might intervene (as discussed above) or things might not be normal—the speaker's idea of what the normal field is may not be correct.

The idea that *ceteris* may or may not be *paribus* brings us back to question of the existential status of s_1. Recall that the problem with the *ceteris non paribus* cases above in event-chaining theories was that the result did not always occur; this created a problem given the existential binding of the result argument in these theories. But of course sometimes the result is entailed to occur, e.g. in a language like English in which (perfective) accomplishments systematically entail their results. To account for such data, we can distinguish cases in which the result happens by adding a presupposition that the successor s_1 occurs; that is, s_0 is judged by the speaker to be efficacious.

2.2.3 Intentions as second-order forces and the Law of Rational Action

Above we have discussed everything that goes into calculating the net force of a situation involving only physical forces, some with prototypically physical effects, like motion, and others that are quite abstract but with physical effects nonetheless, like ripening. We propose next to take another small step of abstraction, noting that the same framework of understanding is appropriate for thinking about "psychological forces" as well. Just as we can speak of pushing or putting pressure on an object, we can also speak of pushing or putting pressure on someone, in a psychological sense, to accept an idea or to perform an action. Because the psychology in such a case often involves more than one person, we will say such pressure is "psychosocial".

The idea that the conception of the physical world is co-opted for use in the psychosocial domain is present in Jackendoff (1987 et seq.) and Lakoff & Johnson (1999), among many others (see, e.g., Bloom, Peterson & Garrett 1999 for a representative sample). Talmy (1988, 2000, a.o.) has extensively championed the view, drawing in part from Sweetser's work (1982, 1984), that force dynamics is the way to understand this link between the physical and the psychosocial. For example, while the sentence in (14a) is "force-dynamically neutral," the sentence in (14b) conveys that some other force, whether physical or psychosocial, prevents the subject from leaving the house if he wants to.

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take (possibly multiple) propositions and return other propositions that are inferred to be true in case there is no opposing information to the contrary. The speaker then chooses an initial situation compatible with their default (informationally *ceteris paribus)* belief state.

(14)   a.   John doesn't go out of the house.
        b.   John can't go out of the house.   (Talmy 2000 (1): 412)

Wolff (2007) has tested this idea experimentally, showing subjects a scene in which a pedestrian wants to go in a certain direction and a policeman directs her to go in a certain (possibly different) direction, and asking his subjects if the policeman *caused* the pedestrian to reach her destination, *enabled* her to reach her destination, or *prevented* her from reaching her destination. The results exactly parallel the results obtained in scenarios where inanimate objects are exerting forces on each other.

How does intentional action fit into our calculation of the net force? It cannot do so directly, as intentions are not physical forces. We can't even represent them with the same type of function, i.e., as functions from situations to situations. The reason for this is the intensionality of desire (Heim 1992, Portner 1997, e.g.). When an entity desires something, they desire not a particular situation, but rather a property of situations; when you want to be happy, all you care about is that your being happy holds of the situation in question.

Copley (2010) proposes an analysis of intentions that treats them analogously to our formal treatment of forces, but assigns them a higher type, to account for the intensional nature of desires. Rather than being functions from situations to situations, desires are functions from situations to properties of either situations or forces. Like regular "first-order" forces, these desires, which we might call "second-order forces," can have magnitude and can be used to calculate an intention as the "net desire" of an entity in a situation (see also Copley 2008, 2009 for 'commitment' as including the notion of net desire).[29]

We assume (with, among others, Davidson, 1963 and Fodor, 2000) that intentions, given the right circumstances, cause things to happen in the world. The remaining piece of the puzzle is a link between intentions and happenings explaining how intentions cause things to happen. The link we will appeal to is essentially the one proposed by M. Smith (1988) and bears a close relation to discussion in Portner, 1997, namely, that rationality constrains an entity's actions to those that advance progress towards the entity's intended goals. We will implement this idea by proposing that volitional individuals are subject to a normal field tendency which we will call the Law of Rational Action. The Law of Rational Action governs any individual who has an intention in a situation and says that if such an individual has an intention (a net desire) for p, and judges that there is a path of action which will lead to a situation that satisfies p, then that individual is the source of (physical/first-order) forces which will result in a later situation along the *ceteris paribus* causal chain of situations that does satisfy p.

(15)   *Law of Rational Action*: If an individual x has a net desire for p in a situation s, x is the source of a force which has a later situation with property p, as long as nothing prevents x from being the source of such a force.

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[29] We want to be careful here to distinguish between abstract first-order forces on the one hand, and true second-order forces on the other hand. The distinction between first-order and second-order forces is not simply the difference between the physical and the psychological realm, as there are abstract first-order forces that are psychological in nature, such as getting angry or frightening someone.

Again, the individual's perspective—her representation of the initial situation and the normal field—will determine the metaphysical model; in general, whether or not there is a later situation with property p in the causal chain depends on what the individual's perspective is .[30]

The LRA provides a way to think about intentional action, that is, acting to achieve a goal[31] An intentional action is one that arises because of the LRA; in other words, it is a force whose source is an individual x and the reason that individual is the source of the force is because x has an intention (a net desire) for p; from x's perspective, the force is expected to lead to a situation of which p holds.

The distinction between intentional and other actions is relevant to lexical distinctions dependent on volitionality, such as the contrast between *murder* and *kill,* among many other issues. A full implementation of intentionality and agency will take us too far afield here, however; we will leave a full discussion of psychological forces and agency for future work. We merely provide the above sketch to illustrate how intentional action can be incorporated into the present framework.

2.3 Interlude: the status of "event" and "state"

We have explicated the metaphysical basis for our notions of 'situation' and 'force', and detailed some of the key intuitions about forces that we intend to appeal to in our formal treatment and analyses below. Before presenting our formal implementation, however, we would like to address the status of intuitions about the words typically used to talk about eventualities, i.e., "event" and "state", in a framework that does not include anything called either an "event" or a "state".[32]

Many of the generalizations about predicates of events in Davidsonian frameworks will turn out to be generalizations about predicates of forces in the present approach, and similarly for states and situations. In this sense, it's more or less correct to say loosely that events are analogous to forces, and that states are analogous to situations; forces and situations play roughly the same roles in denotations as events and states, respectively. However, it is worth pausing here to be clear about the extent to which these analogies hold.

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[30] Heim (1982) argues that there is an element of belief in the denotation of *want,* based on sentences such as *John wants to sell his cello,* which if true entails that John believes himself to have a cello. For Heim, if *want* quantifies over the metaphysically possible worlds, then there would be no cello of John's to refer to in those worlds. In John's belief worlds, however, there is such a cello. In the treatement of desire we have sketched above, there is no appeal to belief. However, as usual, the metaphysical model involved stems from the individual's perspective (choice of initial situation and normal field). In the case of John's cello, his representation of the initial situation would include him having a cello. See also Kamp, 2007, for a similar way to account for intensionality by means of individuals' Discourse Representation Structures.

[31] The notion of action to achieve a goal has been of interest especially on the more philosophical side of linguistics; e.g., Kamp (2007), Van de Velde (2011). In event-chaining conceptions of causality, however, action to achieve a goal is often left unanalyzed, while in possible world approaches—notably the literature on anankastic conditionals, Sæbø 2001, Huitnik 2005, von Fintel & Iatridou 2007, von Stechow et al. 2008—action to achieve a goal has proven to be quite resistant to analysis (Nissenbaum 2005, Fernando 2005). Work on imperatives has been more forthcoming in this respect (Portner 2007, Condoravdi & Lauer, 2010, e.g.).

[32] In standard Davidsonian frameworks, both of these notions are modeled with a single argument type which is called either an "event argument" or an "eventuality argument", sometimes with a further division of eventive and stative subtypes of such arguments (cf., e.g., Kratzer 2004). In most of our discussion below, we are using the terms 'event' and 'state' in their everyday senses; in particular, 'event' will encompass eventive eventualities but not stative eventualities.

Let us start by comparing situations with states, as the simpler case. Our intuition of what a state is corresponds to a rather minimal situation. A situation of which *The door is open* is true might have something else true of it, as well as other individuals in it, but intuitively, a state of which *The door is open* is true has only the open door in it, as the door is the only participant in the eventuality. Thus, while we will treat stative predicates as being true of situations, and while intuitively all states correspond to situations, it is not exactly correct to equate situations with states, since intuitively not all situations map to states.

Turning to the analogy between events and forces, we can likewise ask whether the analogy holds in both directions: Do all the things we call 'events' map to 'forces' in the present framework? And do all the things we call 'forces' map to 'events'? We will take each in turn.

We must first ask what we mean when we call something an "event". There are two hats worn by the word "event": the first is our use of it to designate happenings in the world, in whatever way our senses and cognitive apparatus detect them -- typically, when a change occurs (see, e.g. Cleland 1991: 245). The second hat worn by the word "event" is its use to refer to Davidson's reified event arguments. Davidson's implicit assumption was that our intuitions about happenings match the properties of the thing he saw in language, which he thus named accordingly. We've already proposed that Davidson's "event" argument should be replaced with, in fact, two types of arguments, which we call forces and situations. We call them this because their behavior matches up well with our intuitive notions of what a "force" and a "situation" are. Our question here is: what is the relationship between our intuitions about "events" and our intuitions about "forces"?

As far as we can tell, it is true that everything normally called an "event" will turn out to correspond to the net force of some situation. In general, the net force of a situation will trigger an evolution of that situation into another situation, which is a fair description of the usual change-based intuition about what an 'event' is. However, as emphasized above, because of the *ceteris paribus* condition, forces are defeasible, while events are not; either a change happens or it doesn't. There is therefore no identity between events and forces, but there is certainly a correspondence, such that all 'events' can be associated with the net force of some situation.

What about our intuitions about referents of the word "force"? Do all the things we typically call "forces" map to things we typically call "events"? We consider two mismatches below. First, forces do not necessarily entail change, while the notion of an "event" may well be best characterized by change. Second, 'force' in everyday parlance can naturally refer to a kind, rather than an individual, while 'event' typically refers to an individual.

As should be clear from our discussion above, if events are understood to be characterized by change, then not all "forces" correspond to "events". There are plenty of cases where force is applied but nothing seems to change. A force changes a situation only if no stronger force keeps it from doing so. So, for example, if you push on a cup hard enough to overcome the friction between the cup and the table it is sitting on, the cup is set in motion. The input of energy results in the change from the initial to the final situation.

On the other hand, not all forces result in change, so not all forces will have a corresponding event, assuming that change, rather than energy, is the characterizing property of events. For instance, suppose that you push on a stationary cup, but that you do not push hard enough to overcome the force of friction on the cup. Nevertheless you are still applying a force by pressing against the cup. This force has essentially no effect because an opposing force, namely, the frictional force of the cup on the table, is stronger. Since nothing changes, this is not an event—*if* events necessarily involve change. It is worth noting that on this understanding of

events, language does not refer to events (so far as we know, based on the data commonly discussed in the literature); the Davidsonian "event" argument refers to something dynamic—that is, an input of energy—rather than something changing (when it does not refer to a stage-level state). The English progressive, for instance, is a reliable test of dynamicity, not of change, since the progressive applies happily to predicates like *keep* and *stay* where nothing changes (e.g., *Friction is keeping the cup on the table/The cup is staying on the table)*. Predicates like *keep* and *stay* are mainstays of the cognitive linguistic force-dynamic literature, but not well-explained in the formal literature. The ability to refer to forces -- crucially involving inputs of energy -- will enable us to provide a formal analysis of predicates like *keep* and *stay.* We will expand on this idea below in section 5.3.

The difference between the natural classes of dynamic (or "eventive") predicates and stative predicates has been held to be about energy in the linguistic literature, as we saw above in section 1.5. In contrast, philosophers have been concerned with the non-linguistic question of what an event is (as well as the relationship of this notion to language), as in, e.g. Cleland 1991 and references therein. Given that our goal here is to name the entities which, according to the linguistic evidence, account for a natural class of predicates, the term 'force' is more appropriate--*keep* and *stay* share the key linguistic properties of other 'eventive' predicates. 'Force', therefore, as a more inclusive term which applies naturally to these predicates, is a better match for the data than 'event'.[33]

The second mismatch between the term 'force' and the term 'event' has to do with the former's mass/count ambiguity. Events are clearly individuals, which is a necessary characteristic for any candidate for the job of a Davidsonian argument.[34] The word 'force', on the other hand, refers sometimes to individuals or tokens, as in *the force arising from the interaction of this 2-kilogram mass and Earth's gravitational field'* and sometimes to kinds or types, as in t*he force arising from the interaction of* a *2-kilogram mass and Earth's gravitational field. '*[35]

The literature on events takes care to distinguish event tokens from event types; consider, for example, Carlson's (2001) discussion of 'event' as a sortal predicate:

> A few preliminary words about events before we go any further. By "event" I intend spatially and temporally bounded, ephemeral constituent of the world that has but a single occurrence. These are to be distinguished from event-types, which unlike (token) events may occur and re-occur. ...I also do not think that the noun "event" itself is a sortal. Asking how many events have occurred at a given time is like asking how many "things" there are in a room at a given time. It is only when a sortal concept is invoked that we can get clear answers to such questions (e.g. how many takings of a test, or how many people). Nevertheless, I persist in locutions asking us to count "events". (Carlson 2001: 39)

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[33] Could we use the word "event" for a (dynamic version of the) Davidsonian argument as long as we understood it to be about energy? This redefinition would not suffice without the introduction of the *ceteris paribus* condition, which comports well with our understanding of "force"; less well with "event", which as we have said does not obviously allow for defeasibility. In addition, treating an "event" as involving energy does not match the intuition that the word "event" refers to a change (Cleland 1991).

[34] Though see Gehrke (2011) on Davidsonian arguments that represent event kinds.

[35] As mentioned above in footnote 23, there is also a colloquial neutralization of 'force' and 'field' in that people talk about 'the force of gravity' when intending to talk about a gravitational field; again, such uses of 'force' are not relevant to our technical use of the term as a Davidsonian argument here.

Similarly, the 'force' entity we are introducing is a spatially and temporally bounded constituent of the world that has but a single occurrence. We thus do not consider type-denoting uses of 'force' as relevant to its use as a technical term in the framework we are developing here.

Having clarified the relationship between our proposed ontology of forces and situations and the words "state" and "event", we now return to our main theme. In the next section, we present the formal characterization of the model we are proposing.

3.   A force-theoretic model

3.1 Formal details

Recall our proposal that a force should be thought of as a function 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 (16) and (17) below, along with a description of the normal fiend in (18).

(16)   *Situations:*
          A situation s is spatiotemporally bounded "annotated snapshot" of individuals and their
          properties.

(17)   *Forces:*
          A force consists of energy. Energy arises from individuals, their properties, and/or the
          interaction of these with the normal field.

(18)   *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.

To represent situations in a Montagovian semantics, we assign them the primitive type s[36].

(19)   *Type of Situations:* s.

As we have said above, we propose to represent forces as functions from situations to situations:

(20)   *Definition of Force:* A force f is a function from an initial situation to the (ceteris
   paribus) final situation, i.e., it is of type $\langle s,s \rangle$.

The idea behind the $\langle s,s \rangle$ type is that 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, according to the laws of naïve physics. For convenience we will abbreviate type $\langle s,s \rangle$ as type f.

Because forces arise from individuals and their properties in situations, we can relate forces to situations. When a force arises from all the individuals and properties in a situation, it is

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[36] We take our approach to type theory in natural language from Heim & Kratzer (1998).

the *net force* of the situation. The net force, as discussed above, yields a unique output situation. Supposing that the laws of naïve physics are deterministic, 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. The diagram below depicts such a causal chain (the vectors are depicted *in* the bubbles because the forces arise from the situations represented by the bubbles).

(21)   Causal chain of situations with net forces
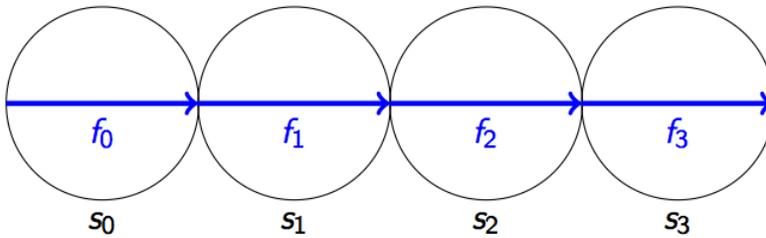
We assume that for a given situation s_n, we can always recover its net force f_n.

(22)   net(s) =:   the net force of s

Using the function *net* (by means of its inverse *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.[37]

(23)   a. init(f) = net^{-1}(f)
        b. fin(f) = f(net^{-1}(f))

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

(24)   a. suc(s) = fin(net(s))
        b. pred(s) = suc^{-1}(s)

As usual, individuals will be represented by variables x, y, z... and will have type e. Stage-level stative predicates are predicates of situations, type <s,t>, and are represented by lowercase Roman letters p, q, etc. Dynamic predicates are predicates of forces; they have type <f,t> and will be represented by lowercase Greek letters π, ρ, etc.

3.2 Efficacy and the ceteris non paribus cases

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[37] As noted by a reviewer, the job done by fin(f) could equally be described in terms of the init function, as fin(f_0) = 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 dealing with the initial and final situations of a force; see also, the 'beg(e)' and end(e)' functions in Kennedy (in press).

A situation s_0 is *efficacious* just in case its *ceteris paribus* successor situation occurs. As described in section 1.4 above, 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^a_0 is the efficacious situation; in that case, given her conception of the contents of that situation and the normal field, she is judging that no forces from outside s^a_0 will intervene, so that s^a_1 will indeed occur. Of course, something from outside s^a_0 may well intervene, in which case perhaps the efficacious initial situation is s^b_0 and what will occur is *its* successor s^b_1.[38]
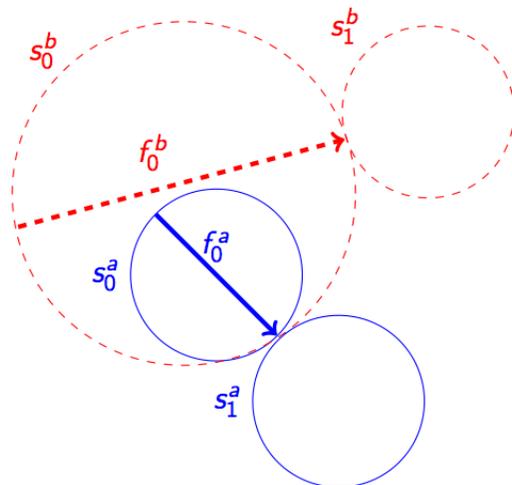
Fig. 1

The notion of efficacy allows 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.[39] As we mentioned above, this makes the non-culminating forms illustrated in (7)-(10) 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, 2007, and this is consistent with their comparatively unmarked morphological structure.

The meaning of the English progressive 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 $<<f,t>, <s,t>>$ (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

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[38] 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.

[39] In fact, we have proposed elsewhere that there are forms which explicitly presuppose that the initial situation is *not* efficacious: the 'frustratives' of Tohono O'odham and Amahuaca (Copley & Harley, to appear).

predicate of forces (π, the denotation of the vP), 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.[40]

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

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:

(26)   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 (26a) is concerned, it seems at first glance that the current situation referred to in the first clause of (26a) is *not* efficacious. There is no presupposition that John finished the cake; if there were, the continuation in (a) would be infelicitous. On the other hand, (26b) is somewhat infelicitous (the only reading involves taking John's perspective). The difference between (26a) and (26b) is that in (26a) 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 any forces generated by the normal field—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 (26b) presumably 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 (26b) the speaker has to pick the *present* situation that they *currently* think is efficacious, and it is apparently odd to change one's mind mid-sentence about which situation s at the present time is efficacious; however, the acceptability of (26a) (as well as the perspective problem discussed above in section 1.4) 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 situation can make it look as though it does not.[41]

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[40] We assume that this presupposition is projected from the little v below the progressive, and is not part of the meaning of the progressive itself.

[41] We leave aside here the issue of how to implement the relativization of judgments of efficacy to times and speakers, as well as many other questions raised by the extensive literature on the English progressive. We anticipate, however, that the inclusion relation (Klein, 1994, e.g.) in imperfectives may have a role to play in the progressive as well, which in the force-theoretic framework means that the denotation would make reference to substitutions of the initial situation.

In the remainder of the paper we will investigate how the force-theoretic model is to be implemented in a semantics of natural language. We will first consider how it integrates with syntactic structure, and subsequently, in section 5, we will show how the model accounts for distinctions between dynamic and stative predicates.

4. Argument structure and event structure

We now turn to the integration of the force-theoretic model with the current understanding of verbal argument and event structure. Let us consider how we capture eventuality types and their argument-structural properties. We have proposed that the foundational distinction between stative and dynamic predicates is that stative predicates are predicates of situations, type $<s,t>$, while dynamic predicates are predicates of forces, type $<f, t>$. We will first consider how the various subclasses of dynamic predicates are composed, beginning with changes of state.

4.1   Changes of state

Among syntacticians working on the argument structure/event structure interface, a general consensus has emerged on the basic internal structure of the *v*P. For change-of-state predicates in particular, there is also general agreement on the semantic contributions of the various subpredicates that compose to generate the vP's denotation (Van Valin 1990, Hale & Keyser 1993, Borer 1998, 2005, Kratzer 1996, Ramchand 2008, among many others). As we pointed out above for accomplishments in section 1.1, the literature generally treats change-of-state predicates like *melt* as having (at least) two components: a causing event and a result state. In the current proposal, the causing event corresponds to a force which is applied to a situation where the resulting stative predicate does not hold; this force (*ceteris paribus)* yields a situation where the resulting stative predicate does hold, following Dowty (1979).[42]

Standard approaches to the syntax/semantics relationship take each subcomponent of a change-of-state predicate to be introduced in a separate syntactic projection, meaning that a change-of-state-denoting vP minimally contains two phrasal projections.[43] The lower portion of 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 $<s,t>$). 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 $<f,t>$). The v° head introduces a force f and asserts that p holds of the final situation of that force—that is, it identifies *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 ~p situation.[44] (Recall that by the definition in (23a) init(f)=s if and only if net(s)=f, so the initial situation of f is the situation of which f is the net force.)

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[42] 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. The relationship between this proposal and a Lewis/Dowty-style counterfactual understanding of causation will be discussed below in section 6.2.

[43] 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.

[44]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 &

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 is the locus of the presupposition that init(f) is efficacious; that is, that fin(f) occurs.

(27) $[\![v_{become}]\!] = \lambda p\ \lambda f\ .\ \sim p(init(f))\ \&\ p(fin(f))$
        presupposed: init(f) is efficacious

The structure of the vP in this case is the following:[45]

(28)

$vP_{<ft>}$
- $v_{<st,\ ft>}$: (become)
- $SC_{<st>}$
  - $DP_{<e>}$: the door
  - $\sqrt{OPEN}_{<e,\ st>}$: open
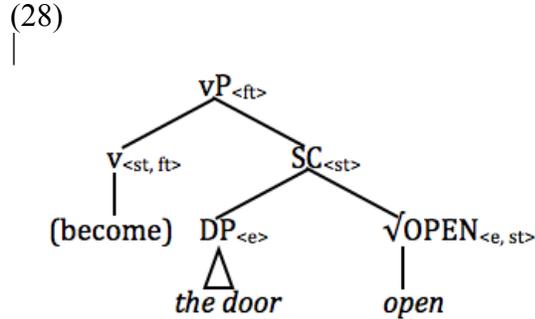
In the transitive alternant (*John opened the door*), we assume that the external argument is introduced by a Voice head, as argued by Kratzer 1995, Pylkkänen 2002, Cuervo 2003, Harley 2012, among many others. This head takes a predicate of forces as its complement and returns a function from individuals 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.
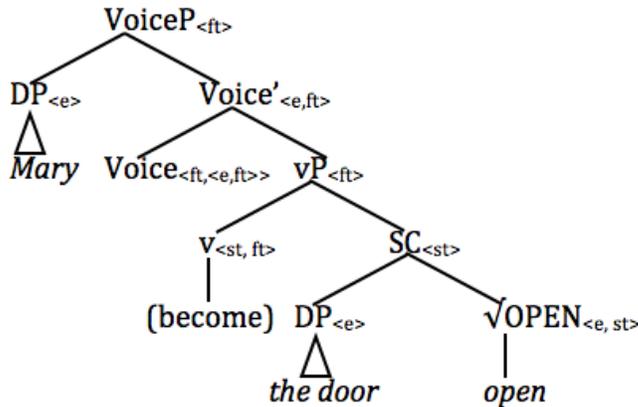
(29) $[\![Voice_{ACTIVE}]\!] = \lambda \pi\ \lambda x\ \lambda f\ .\ \pi(f)\ \&\ source(x,\ f)$

The structural representation of the transitive alternant is below:

(30)

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 (in press) shows that deadjectival verbs of this class always behave morphologically as if a comparison of degrees is involved, and argues 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.

[45] 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).

VoiceP$_{<ft>}$

DP$_{<e>}$ Voice'$_{<e,ft>}$

Mary Voice$_{<ft,<e,ft>>}$ vP$_{<ft>}$

v$_{<st, ft>}$ SC$_{<st>}$

(become) DP$_{<e>}$ √OPEN$_{<e, st>}$

the door open

Examining the types associated with each node in the trees in (28) and (30) above, it is clear that no special composition operation need be invoked to bring together the different parts of the complex vP; Functional Application will suffice in each case. As we discussed above in section 1, this gives the present theory an advantage over event identification as well as the event-chaining approaches that introduce a novel compositional principle.

Note that the vP in these change of state predicates has the type $<f,t>$, which is the type of a predicate of forces, or equivalently for us, a dynamic predicate. We assume that what aspect on dynamic predicates does is to take a predicate of forces and relate it to a (reference) situation, so that the AspP has the type $<s,t>$ (Klein, 1994, Kratzer, 1998). This is analogous to the well-known idea 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 $<s,t>$, with Tense relating the situation introduced by Aspect to the situation of utterance (cf. Klein, 1991, e.g.).

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 two maximal projections of type $<s,t>$: the small clause denoting the result state (the predicate of 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:

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

(32)   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.

(33)   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.

For *again,* we introduce a relation < to denote a situation earlier than s; this could in fact be defined strictly using causal chains, without recourse to times. However, we will need to introduce times to define the temporal trace function τ in the usual fashion (Link 1987, Krifka 1989) for *for two minutes,* and a function *duration* that returns the duration of an interval. We assume that adverbials such as *for two minutes* compose via Predicate Modification,[46] though nothing particularly hinges on this choice.

(34) a. $[\![$again$]\!]$ = λp λs . p(s) & ∃s' < s : p(s')
      b. $[\![$for two minutes$]\!]$ = λs . duration(τ(s)) = two minutes

Given these denotations, these predicates will adjoin freely to the embedded small clause predicate of situations in (28) and (30) above to yield the low reading. Similarly, they will adjoin to the higher AspP, following the composition of aspect with vP, 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 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:

(35) 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 (30) above, however, we would predict a low-scope reading for the sentence in (36a) where *for two hours* would take the temporal trace of the existence of the painting as its argument; compare (36b) to (33a):

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

There is no reading for (36a) in which the painting exists for two hours. The only reading available is the high reading, where *for two hours* adjoins the AspP. We take this to indicate that there is no lower type <s,t> node to which the adverbial phrase *for two hours* can adjoin.

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[46] Predicate Modification is argued (Heim and Kratzer 1998) to be a second rule of composition (after Functional Application). It says that for any type x, two constituents of type <x,t> can combine intersectively to form a higher node of type <x,t>: if x is a type and where α is a node and β and γ are its daughters, and both β and γ are functions of type <x,t>, then $[\![$α$]\!]$ = λy . $[\![$β$]\!]$(y) & $[\![$γ$]\!]$(y), where y is of type x.

The assertion of the existence of an incremental theme (or its non-existence in the case of destruction/consumption verbs) then, must be semantically, rather than syntactically introduced. Such a verb is a predicate of a force which has the effect that an individual which was not in the initial situation is in the final situation. We have said before that situations are composed of individuals and their properties; we now formalize 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 x is in the situation 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 (37) below. It ensures that the object 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.

(37) $[\![v_{APPEAR}]\!] = \lambda x \lambda f . \sim[x \in init(f))] \, \& \, [x \in (fin(f)]$
         presupposed: init(f) is efficacious

The structure of a sentence like that in (35a) above, then, is illustrated in (38):

(38)
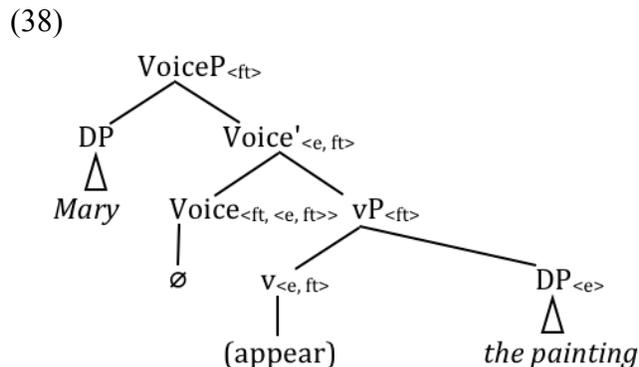
The sentence in (35b) has the same structure as (35a), but with *music* as the complement of the v head. (35a) and (35b) however contrast in an important way that we have not yet addressed: with a bounded object such as *the painting* the predicate is telic, while with a unbounded object like *music* the predicate is atelic. One test for telicity is that telic predicates are acceptable with *in* phrases, as in (39a) while atelic predicates are marginal, or receive an inchoative reading (Vendler 1967); thus (39b), if it has any acceptable reading, can only mean that Mary started to make music at the end of an hour.

(39)   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 (35a,b) has been accounted for in the event-based literature via Krifka's (1991) homomorphism function, which

maps subparts of incremental theme objects to subparts of events; unbounded objects thus lead to unbounded creation/destruction events. Within the force-theoretic framework, this relationship will operate somewhat differently, hingeing 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 init(f) and fin(f).[47] The *in* phrase adjoins to the vP which is type $<f,t>$ (and thus, incidentally, is not compatible with stative predicates, which are type $<s,t>$). 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.

(40) $\llbracket$in an hour$\rrbracket = \lambda f$. duration(τ(init(f)) - τ(fin(f))) = an hour

In (39a), this works exactly as one might expect: for (39a) 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 made music* in (39b), 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 of succession (s_1 is after s_0).

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"; Talmy makes the same distinction, between "point" and "extent" causation; McCawley (1976:119) distinguishes "continuous causation", and van Lambalgen & Hamm (2005) 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 (1991) 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 (39b), for example, the initial situation s_0 (i.e. init(f)) includes Mary and certain of her properties, such as her intention to make music. The result of Mary's intention (via the Law of Rational Action) 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,*

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[47] Note that definition of force allows reference to fin(f) without having to look down further in the tree than the denotation of the $<f,t>$ node (either VoiceP or vP) that it is adjoined to; thus we avoid having either to violate compositionality (see Dowty 1979 on exactly this issue, in his discussion of Tedeschi's (1973) account of progressive (p. 136)), 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.*

the moment there is a bit of music, then s_1, that is, 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 is no interval between the beginning of s_0 and the beginning of s_1, because of the existence criteria for an unbounded individual like music.[48]
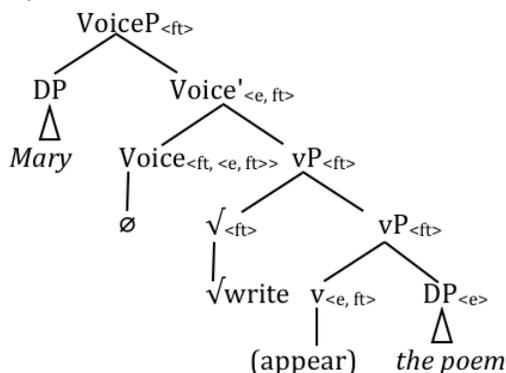
      If we like, we can introduce space between the onset of s_0 and the onset of s_1 by assuming Mary to have had the intention to make music for a while (an hour perhaps) before starting to make music. Her intention is the property in s_0 from which the Mary-make-music force arises, by means of the LRA. 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 is derived.[49]

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, they are considered to modify the initiation or causation subevent in an articulated subevent syntax (see, e.g. Levinson 2007, Ramchand 2008, Embick 2010). In the present framework, the lexical content of such verbs will be treated as a predicate 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:[50]

(41)

            VoiceP$_{<ft>}$

    DP   Voice'$_{<e, ft>}$

  Mary   Voice$_{<ft, <e, ft>>}$ vP$_{<ft>}$

          ø   √$_{<ft>}$ vP$_{<ft>}$

              √write v$_{<e, ft>}$ DP$_{<e>}$

                    (appear) *the poem*

Assuming the verbal root √*write* to denote a property of forces as in (42a), the denotation of the higher vP will be as in (42b); 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.

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[48] 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.

[49] For statives with inchoative readings such as *The door was open in an hour,* our claim would be that there is some head that introduces a force whose final situation is a door-open situation, so that the *in* phrase can be adjoined to a type <f,t> node.

[50] See footnote 46 for a definition of Predicate Modification.

(42) a. λf. write(f)
   b. vP = λf . ~[⟦the poem⟧ ∈ init(f)] & [⟦the poem⟧ ∈ fin(f)⟧ & 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, 2004), according to which morphological 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 1993 for other applications of this proposal).

Indeed, this approach will suffice to analyze manner modification in other contexts than creation/destruction; since manner verbs are predicates of forces, they will always be eligible to adjoin to any node of type <f,t>, 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.[51] Resultatives and manner-of-motion constructions in English, as in (43a) and (43b) respectively, can be productively treated in exactly the same way; instead of adjoining to type <f,t> predicates headed by v_{APPEAR}, such manner expressions will adjoin to type <f,t> predicates headed by v_{BECOME}:

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

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

4.4 Verbs of birthing, activities, and semelfactives

We begin by examining a relatively narrow verb class first considered in detail by Hale and Keyser (1991, 1993): 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*.[52] We adopt this approach to such predicates, incorporating a bare nominal predicate into a v head which is semantically the
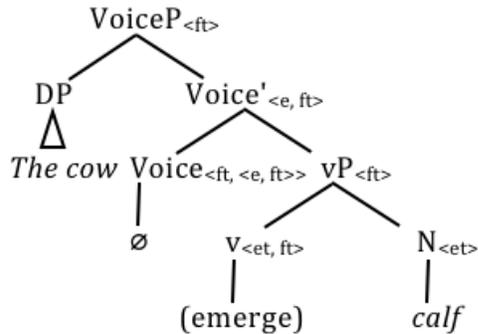
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[51] As noted above, adjacency between the merged heads is a key condition on m-merger. This provides one motivation for treating the external argument as the subject of a higher Voice projection, rather than as an argument of an alternate form of 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 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.

[52] 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.

equivalent of v$_{APPEAR}$ except for selecting a predicate of individuals rather than an individual as its internal argument:

(46)   v$_{EMERGE}$ = λPλf . ~[∃y ∈ init(f): P(y)] & [∃y ∈ fin(f): P(y)]
        presupposed: init(f) is efficacious

(47)

VoiceP$_{<ft>}$
  DP   Voice'$_{<e, ft>}$
  The cow Voice$_{<ft, <e, ft>>}$ vP$_{<ft>}$
            ∅   V$_{<et, ft>}$ N$_{<et>}$
                  (emerge)   calf

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 actual 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:

(48)   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.

Harley (2005) claims that the intransitive analogue to such predicates (lacking the equivalent of 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 equivalents are frequently complex predicates, composed of a light verb and a bare nominal of this kind. 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:[53]

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

(49) $[\![dance]\!] = \lambda f . \, dance(f)$

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

(51)
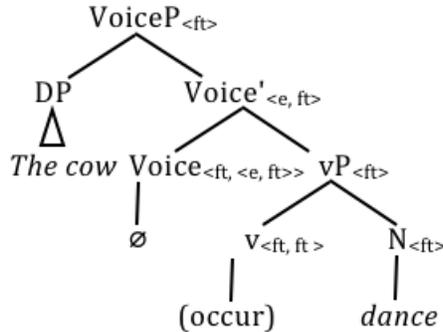
Verbs of emission, such as *glimmer, gleam, beep, ring*, etc. are also predicates of forces in this same sense, derived from their cognate nouns. Again, the few such predicates which occur without a source-specifying Voice head are weather predicates; *thunder* is the best example of this in English.[54]

Semelfactives such as *knock, flash,* and *pat* (Smith 1997) 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 'cycle' quality noted by Talmy, 1985. Activity predicates do not have such a requirement.

Again, as predicates of forces these verbs 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:

(52) a.   She hammered.
  b.   She hammered the metal flat.

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[54] 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 (27), repeated here as (ia).

(i) a. $v_{BECOME} = \lambda p \, \lambda f . \sim p(init(f)) \& p(fin(f))$ (= (27))
  b.   equivalent $v_{BECOME} = \lambda p \, \lambda f . \sim [\exists s \in init(f): p(s)] \& [\exists s \in fin(f): p(s)]$

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

      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}), the source of the famous hyponymous object and cognate object cases:

(53)   a.   She danced a jig.
        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-incoporating langauges like English, they can occur as manners in change-of-state structures:

(54)   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 predicates.

      This latter observation raises possibility is 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), motivated by the fact that 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 <f,t>.

      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 and the Law of Rational Action, 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 (55a), and as a resultative with telic predicates, as in (55b).

(55) 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 (56) 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.

(56) [-te iru]: For any predicate Φ, individual a, eventuality e, and interval t, [Φ-te iru](a)(e) = 1 at t iff there are eventualities e and e1 such that the temporal trace of e equals t and e $\subset$ e$_1$ and [Φ](a)(e$_1$) = 1.

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. 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.)

(57) $[\![$-te iru$]\!] = \lambda\pi\,\lambda s$. $\pi(net(pred(s)))$

For a telic predicate, the final situation is the result state that begins after the initial situation, 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.[55]

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[55] 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
     '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.

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.[56] We here provide some explication of our notion of 'source', connecting it to the literature on external argument thematic relations more generally, and to the continuous vs. ballistic causation distinction from the force-dynamic literature.

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) denied any particular relational content to the external argument role at all; external arguments were simply notationally designated as such, without ascribing an event-structural or thematic 'name' to their relationship to the predicate.

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 in quite a literal sense to indicate that in both cases, the argument introduced by Voice is the origin of energy that is put into the situation; they thus play a 'leading role' in determining the net force of the situation. We have pointed out at least one way in which Agents are distinct from Causers, which is that they become the sources of forces by virtue of the Law of Rational Action, rather than by virtue of their physical properties; Agents are subject to the LRA 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 will have their basis in 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 the 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 (59a); in contrast, Causers cannot be the external argument of activities, as reflected by the need for the telicizing resultative adjective *raw* in (59b) (Folli and Harley 2005, among others).

(59)   a.   John rubbed his skin.

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[56] Note that we do not appeal to syntactically-expressed chains of events: the difference between a causative and an inchoative verb is simply the explicit inclusion of a source argument, introduced by an active Voice head.

b.   The saddle rubbed his skin *(raw).

Recall that activities in the force-theoretic framework involve what McCawley (1976) and van Lambalgem and Hamm (2005) 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 (59) 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 (2006)).

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 visibly transmitted spatiotemporally from other objects. However, it is also not generated in response to the interaction of intentions with the Law of Rational Action. Consequently, such inanimate but telelogically 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 on 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 together these subforces as goal-directed action (see also Tovena 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 futurates such as *The Red Sox play/*defeat the Yankees tomorrow,* as in Copley (2008, to appear), 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.[57]

If this cognitive story is the whole story, we would expect that argument structure is not sensitive to any distinction between Agents and Causers, i.e., neither the ability to generate energy nor the ability to represent goals intensionally is visible to the grammar. We have claimed that the only thing 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.

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[57] 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.

4.6 Cause-introducing PPs

Another set of arguments for a distinct Causer or Cause role comes from the debate over anticausativization approaches to inchoative predicates. It has been argued that certain data from adjoined PP phrases pick out all and only Cause arguments in dynamic predicates.[58] We examine two such cases here.

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. In contrast, *from*-phrases seem to introduce only Cause external arguments, and are well-formed with unaccusatives. This range of facts is illustrated in (60). 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 (60c) 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).

(60) 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, Kalluli 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. Since *by Xself* is possible with inchoative predicates such as the one in (61), Chierchia concludes that inchoatives are underlying two-place causative relations with the external Causer role bound by reflexivization to the internal Theme role.

(61)   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. Our contention is based on the little-commented-upon fact that both kinds of PPs can modify stative predicates, as well as dynamic ones:

(62) a.   The sidewalk was warm from the sun.
      b.   John was pink from embarrassment.
      c.   The casserole was enough by itself.
      d.   Mary was happy by herself.

---

[58] 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.

It would seem implausible to analyze stative predicates like *be warm*, *be pink, be happy*, or *be enough* 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; #Mary was being happy.,* etc.) Consequently, it seems clear that *from X* and *by Xself* phrases do not diagnose the presence of a Cause argument in the semantics of the predicates to which they adjoin.

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 anlaysis for the *from*-PPs.[59] 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. Notice that while (62a). and (b), containing DPs which seem like good candidates for names of forces, are felicitous with a *from* argument, (62c) seems to be elliptical for 'the action/motion/energy/force of the ball' and (62d) is infelicitous, even if understood elliptically. We propose to understand the fact in (62d) and (62e) similarly. In (62e), the name of an Agent cannot be elliptical for the name of a force exerted by that Agent.[60]

(62)   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 (63), as long as the force named by the DP argument of *from* is a desire[61] that would trigger the Law of Rational Action:

(63)   a.   Mary cried out from anger.
       b.   John groaned from the pain.
       c.   Sue called John from a desire to see how he was.

---

[59] The *by Xself* PPs pose a separate kind of problem. It seems to us that their distribution has more to do with their special control-like subject-oriented properties than with the type of theta role they require. It is well-known that the implicit argument of passive verbs is sufficient to control adjoined agent-oriented adverbs, as in *The glass was broken gleefully/to annoy Mary/by knocking it on the ground/with a hammer.* Control by a non-Agent argument is only possible when no implicit or explicit agent is present, as in *Bill died by swallowing his tongue* (Fodor 1971). However, the same implicit argument cannot serve as a local antecedent for the purposes of satisfying condition A (Chomsky 1981), as in *The bed was made in oneself's room.* The ill-formedness of *by Xself* phrases in passives, then, results from incompatible constraints on its occurrence: it must be controlled by an Agent argument if one is present, and, because it contains a reflexive, that controller must also be an appropriate antecedent to satisfy Condition A. The implicit agent argument in a passive can serve the first function but runs afoul of the second; therefore *by Xself* adjuncts are only well-formed in sentences which either have an overt external argument or lack an Agent entirely, as in statives or unaccusatives.

[60] The 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 (via either the gravitational field, as in (62d), or the Law of Rational Action, as in (62e)), as opposed to a (more) direct transmission of energy.

[61] Recall that we wish to treat desires as properties of an individual that nevertheless have a (second-order) force-like nature of their own, see section 2.2.3 above.

d.   The university was shut down (by the governor) from a desire to protect the students.

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 them, 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, like *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 that force was the net force of the situation preceding s:

(64) $[\![from]\!] = \lambda f \, \lambda s \, . \, net(pred(s)) = f$

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.

If we are on the right track here, then we have reason to conclude that syntactic and semantic event-chaining is not necessary. Instead of introducing the causal link between events by a new rule of composition or in a denotation, we have proposed that the causal link itself is the referent of the Davidsonian argument, and shown how this assumption allows for a more streamlined or more empirically adequate treatment of much of the core data which the event-theoretic structures were designed to account for.

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 of the technical apparatus presented here to Davidson'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 (65).

(65)   Mary was happy in the living room.

However, it is clear that not all modifers 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, no clear type-theoretic contrast was introduced 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. 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 explaining the distribution of two temporal adverbial phrases: *for*-phrases (see (34b)) take situation arguments, while *in*-phrases (see (40)) 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 the type-theoretic difference between forces and situations. We will first show that it is easy to implement an analysis of Katz's (2003) generalization about Thomason and Stalnaker's two classes of adverbials. We then provide an implementation of aspectual coercion in response to type clash with the selectional requirements of the progressive 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 like *keep* and *stay*.

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:

(66) a. *John loved Mary quickly.
   b. John kissed Mary quickly

(67) 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 (68), there are no adverbs exhibiting the reverse pattern, compatible with only stative predicates -- the pattern illustrated in (69) does not occur. All adverbs capable of modifying stative predicates can also modify dynamic ones, as in (70). He calls this the Stative Adverb Gap.

(68) a. John kissed Mary quickly.
   b. *John knew Mary quickly.

(69) a. *John kissed Mary blickly.
   b. *John knew Mary blickly.

(70) a. John kissed Mary a long time ago.
   b. John knew Mary a long time ago.

What's needed to account for Katz's Stative Adverb Gap is for dynamic predicates to share something with stative predicates, so as to combine with adverbs like *a long time ago*, but to 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 (a position that Davidson tentatively took himself). 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. As in Katz's approach, it further automatically provides the shared property, because predicates of forces become predicates of situations via the operation of Aspect. Consequently, we expect any adverb that can compose with stative predicates to also be able to compose with eventive predicates, a property we already seen above in our treatment of *for*-modification.

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: The former have a situation argument, and hence also a temporal trace, while the latter are predicates of individuals.[62]

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 shown in (71), it has long been recognized (Partee 1977, Dowty, 1979, Smith 1983, Bach, 1986, de Swart 1998) that certain predicates thought to be stative because they can occur in episodic readings with the simple present, as in (72), can indeed occur with the English progressive, as in (73):

(71)   a.   John was smoking.
        b.   #John was knowing French.

(72)   a.   Mary loves her new neighbors.
        b.   John is very smart about this.

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

---

[62] It is possible, also, that making stage-level stative predicates 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 temporal in character.

Likewise, some stative predicates can occur in imperatives which are also supposed to select dynamic predicates, as shown in (74) and (75):

(74) a. Smoke!
      b. #Know French!

(75) 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 ($<s,t>$) and eventive ($<f,t>$) predicates to motivate an account of coercion in progressive statives. The progressive, we assume, selects an $<f,t>$ predicate.[63] When a progressive or an imperative is applied to a stative predicate like *John love Mary*, the type mismatch triggers a type shift from $<s,t>$ to $<f,t>$.[64]

  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 arguments are subject to the 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

  A long-standing puzzle in the event-structure literature concerns 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.

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

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[63] See section 3.2 above for our denotation for the progressive operator.

[64] 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.

As per the discussion of coercion above, this only shows that these verbs *can* be dynamic. However, the fact that they are interpreted habitually in sentences such as those in (77) with the simple present indicates that they *must* be dynamic:

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

However, in an event-based framework, it is difficult to understand what distinguishes such eventualities from stage-level statives such as *The door is open.* In an event-based framework, 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. In a semantics in which the Davidsonian argument is an event and events are characterized by change, it is difficult to understand the notion of a "eventive" eventuality in which nothing changes.

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 like *The rock kept the door open*, this complement would be [the door open]). The problem with event-based (78a) ("cause to be") and (78b) ("cause to become") is that it is possible to keep something in a location without strictly being the cause of its being there or coming to be there. On the other hand, *keep* might instead be "cause to stay," as in (78c). But in considering an event-based approach to *stay*, as in (78d), 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*.

(78)   a. $[\![keep]\!](x)(p)$ =? $Agent(x,e_1) \quad \& \; CAUSE(e_1,e_2) \; \& \; BE(e_2, p)$
       b. $[\![keep]\!](x)(p)$ =? $Agent(x,e_1) \; \& \; CAUSE(e_1,e_2) \; \& \; BECOME(e_2, p)$
       c. $[\![keep]\!](x)(p)$ =? $Agent(x,e_1) \; \& \; CAUSE(e_1,e_2) \; \& \; [\![stay]\!](e_2,p)$
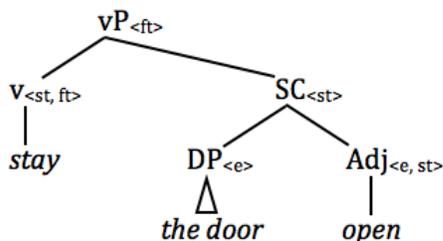   d. $[\![stay]\!](e_2)(p)$ $\neq$ $BE(e_2,p)$

What is needed is a way to represent the idea that dynamic predicates involve the input of energy into a situation instead of a change, which is exactly what we have been advocating above for independent reasons. The intuition about these predicates (cf., e.g. Talmy 2000) is that there is exactly enough force in an initial situation to maintain identity between it and the next situation, against a tendency otherwise. For such cases, consider the subsituation s' identical to the initial situation in all respects except for the absence of the individuals and/or properties that generate the *keeping/staying* force. This subsituation s' has a net force which results in a transition to a final situation which is distinct with respect to p. Thus, *keeping* and *staying* involve an input of force f into 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 f, be a situation of which ~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 force, would differ with respect to p.[65] In contrast, a stative predicate like *The door is open* picks out situations to which no force

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[65] 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

need 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.*[66]

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 <s,t>, and require that this <s,t> 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).
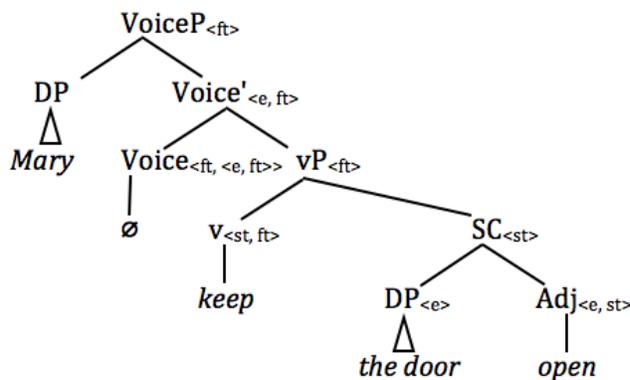
(79)

```
              vP<ft>
            /        \
       V<st, ft>      SC<st>
          |          /      \
        stay     DP<e>      Adj<e, st>
                  △           |
              the door       open
```

(80)   ⟦v_STAY⟧ = λp λf . p(init(f)) & p(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. [67]

(81)

```
                  VoiceP<ft>
                /            \
             DP           Voice'<e, ft>
             △            /          \
           Mary    Voice<ft, <e, ft>>   vP<ft>
                      |              /        \
                      ø        V<st, ft>      SC<st>
                                  |          /      \
                                keep      DP<e>     Adj<e, st>
                                           △           |
                                       the door       open
```

---

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

[67] 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 <f,t> constituent [run around all day] to an appropriate <s, t> predicate.

We thus treat *keep* as a transitive suppletive variant of *stay*, in the same way that *raise* is allomorphically related to *rise*, *lay* to *lie, teach* to *learn*, and *feed* to *eat*.[68] Both *keep* and *stay* are dynamic predicates, but do not provoke a change. 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.

6. Concluding thoughts

6.1 The theoretical and empirical pictures

We began the paper with a theoretical problem—how to chain events without adding an additional rule of composition or a stipulation in a denotation—and an empirical 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. The force-theoretic framework provides our answer to both problems; 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.

6.2 The nature of causation?

   The problem at the center of our discussion has been to investigate how language refers to concepts of causation, rather than what causation is actually like. We are not here attempting to discover anything about the nature of causation itself; we leave that question to the philosophers. However, we would like to situate our proposal, not only with respect to the

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[68] 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, for example '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 regular 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 53 above.

standard formal linguistic analysis of causation (that of Dowty, 1979), but also with respect to existing philosophical debate, in order to clarify the ontological commitments of the force-theoretic framework.

There is currently no widespread consensus among philosophers on how to account for causation. We may distinguish two basic kinds of theories: dependency theories and process theories. In the former, the dependence of an effect on a cause can relate, for instance, to regularities (as in the work of Hume; see Garrett, 2009), to statistical probability (Reichenbach, 1971, Salmon, 1988, Pearl, 2000), or the counterfactual claim that if the cause had not happened, the effect would not have happened (Lewis 1973a,b, e.g.). In the latter, a quantity such as energy, heat, momentum, etc. is transferred or exchanged between two entities (Aronson, 1971, Fair 1979, Kistler, 1999, Dowe 2000).

There are *prima facie* problems with each kind of theory. The major issue for dependency theories is that of *causal preemption:* suppose John and Mary both shoot at a bottle, one after another. John's bullet hits first, but Mary's is right behind, and if John's bullet hadn't been there, the bottle still would have broken because Mary's bullet would have hit it. For dependency theories, it is not trivial to say in this case why John's firing the shot caused the bottle to break, since it did not raise the probability of the bottle breaking and the bottle still would have broken in its absence. Process theories fare better with causal preemption; John's firing the shot caused the bottle to break because there is a mechanical chain from John's pulling the trigger to the bottle breaking. However, processprocess theories have their own problems, of which the most pressing is that of *causation by omission.* If, for instance, you kill a plant by not watering it, it is difficult to say what quantity was transferred between yourself and the plant. On the other hand, dependency theories have little trouble with causation by omission.[69]

Our force-theoretic framework is clearly in the spirit of the process theories; however, the most influential theory of causation in formal linguistics, that of David Dowty, relies on a dependency theory, drawing its inspiration from Lewis's counterfactual theory of causation, as shown in Dowty's (1979: 108) conception of φ CAUSE ψ, given below (" \→" is Lewis's counterfactual).

(82)   a. φ depends causally on ψ iff φ , ψ, and not-φ \→ not-ψ are all true.

b. φ is a causal factor for ψ iff there is a series of sentences φ, $φ_1$, ...$φ_n$, ψ (for n ≥ 0) such that each member of the series depends causally on the previous member.

c. [φ cause ψ] is true iff (i) φ is a causal factor for ψ, and (ii) for all other φ' such that φ' is also a causal factor for φ, some not-φ-world is more similar to the actual world than any not-φ'-world is.

To be clear: anyone who uses a CAUSE relation and cites Dowty (1979) without further explanation is relying on Lewis's counterfactual account of causation, though this is rarely made explicit in the literature.

Lewis's theory of counterfactuals (Lewis 1973a, b, c e.g.) takes up an idea proposed by Stalnaker (1968) to the effect that the counterfactual 'if it were the case that p, it would be the

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[69] One emerging line of thought called "causal pluralism" (Cartwright, 2004, and others since) holds that causation is not a unitary phenomenon, so that no single theory may be successful in explaining all cases that intuitively involve causation.

case that q' (p $\setminus\to$ q) is true just in case the most similar p-world to the world of evaluation is a q-world. Lewis is thus committed to an idea of 'degree of similarity'' of worlds, and assumes that it is always possible to find a world most similar to the world in question. Leaving aside the specific details of Lewis's model, we can see that for Lewis, causation is expressed in terms of possible worlds, which are viewed as more ontologically basic than causation.

In the force-theoretic framework, however, we relate causation to possibilities in a different way: causation is taken to be something that is in principle observable (as in process theories),[70] through net forces of situations, so it does not need explanation in terms of possible worlds. Like processprocess theories, causation by preemption is not a problem (because some transmission of energy is involved from the actual cause to the effect), but causation by omission must be addressed.

As Wolff, Barbey, & Hausknecht (2010) Wolff, Hausknecht, & Holmes (2010) and Wolff (to appear) argue, however, cases of causation by omission with predicates such as *prevent* can be understood from a process theory viewpoint as chains of force-dynamic interactions; so, for instance, we might extend his theory to analyze the dropping of an object as the removal of a holding force that opposes a normal field force. From a linguistic perspective, the only issue remaining to be addressed by such an approach is an understanding of why the source of the force that removes the holding force can occur as the subject of *drop*.[71] Indeed, it is evident that the source(x,f) relation that is introduced by Voice is not as simple as we have posited in this paper. As is well-known, in English, certain instruments can be subjects:

(83)   a. The knife cut the bread.
        b. The key opened the door.

For us this means that in English at least, these instruments can be sources of forces. Thus there is something to understand about why John can be a source in *John cut the bread,* given that the knife is in some sense a more proximal source than John is. So we need to understand more about how causal chains work in determining the source relation in different languages, which should also shed light on the causation by omission cases; we look forward to future work on this topic. Assuming, then, that further refinement of the source relation will be able to address these questions, we feel that our framework is on a sufficiently sound footing to merit consideration as a serious alternative to dependency theories of causation in language, such as Lewis's (and Dowty's) counterfactual theory of causation.

We still do need to explain how counterfactual possibilities arise; we accomplish this by means of the speaker's choice of an efficacious initial situation. Such a situation develops via its net force into a successor situation, ceteris paribus; on the other hand, the speaker may not have chosen the initial situation accurately (that is, the chosen situation may not have been the efficacious one, due to external forces on it) so the successor situation that the speaker expects may not occur (see section 1.4 above). From here it will take but a short step to account for counterfactuals such as "if it were the case that p, it would be the case that q"; we will not attempt a full analysis here, but we will note that entities and properties can be added or subtracted from a hypothetical initial situation, with the normal field operating as usual, to

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[70] Note that we do not maintain that a "force" is equal to a "cause," because to say that something is a cause of something else can be complicated; but we do say that the link from one situation to the next is observable; there is no need for a further explanation of it.

[71] The subject is presupposed to also be the source of the holding force; we don't know if this is relevant.

designate a counterfactual situation. Our approach is almost the inverse of Lewis's: whereas he derives causation from possible worlds, given a judicious approach to the similarity of worlds, we take the workings of causation to be more ontologically basic, and derive possible chains of situations from them, given a judicious choice of the initial situation and the normal field.

So, comparing Lewis's counterfactual (dependency-based) theory of causation and the force-theoretic framework, which one provides a better understanding of causation in language, assuming that there is a single understanding to be had?

As we argued above in section 1.2, the cases in which *ceteris* is not *paribus* (progressives, non-culminating accomplishments) provide strong evidence that the neo-Davidsonian event semantics needs augmentation, to account for the non-existence of the caused element. Traditionally, this augmentation has been done with possible worlds,[72] but as we noted, even Dowty, the midwife of formal linguistics' reliance on Lewis's dependency theory of causation, expressed regret that such extra machinery was needed. It is worth noting, too, that in the non-culminating forms discussed above, there is no morphological evidence suggesting that extra possible-worlds semantic machinery is invoked by these forms. In the force-theoretic framework, the corresponding extra assumptions are not in the semantics but concern the cognitive construction of the model itself, so it is not surprising that there would not be extra morphology in non-culminating forms.

It is worth noting as well that the generation of all possible inertia worlds 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. In the case of physical situations, our cognitive representation of the laws of nature take us from one situation to another. Since these laws determine the next situation that we predict, it is superfluous to posit 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.

Furthermore, looking ahead to the prospect of closer collaboration between researchers from cognitive/psychological and formal semantic perspectives, we note that a theory that treats causation as directly observable, as ours does, is more psychologically plausible than one that derives it from possible worlds, as Lewis's does. There exists, for instance, a subfield of psychology that deals with perception of causation (see, for example, a representative bibliography of work on the topic at http://www.yale.edu/perception/Brian/refGuides/causality.html), but we know of no subfield of psychology that deals with perception of possible worlds.

6.3 Redivisions of labor

We would like to conclude by pointing out several ways in which the force-theoretic framework capitalizes on insights from cognitivist views of causation to provide 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.

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[72] As we and others (Portner, 1998, Szabó 2004, e.g.) have claimed, the partial event approaches represent a glossing over of this particular problem rather than a solution to it.

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. While the extension of the force-theoretic framework to modality is in its very early stages (cf. Copley 2010, 2011), it is attractive to consider that possible worlds might be constructed using the very same elements used to build causal chains in the vP.[73]

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 an additional 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 represents a redivision of labor between cognition and the grammar. Unlike approaches framed in terms of partial events, it aims at a cognitively realistic answer to the complicated question of how a cause can normally, but not necessarily, provoke an effect; unlike approaches invoking situations as partial possible worlds, the answer is situated in the cognitive faculty rather than the linguistic semantics. We feel that this is an important distinction to make, and one which is subject to empirical verification.

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[73] See Cipria & Roberts, 2000, and Del Prete, to appear for other accounts involving chains of situations extending into the future.

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