

An ontology for a force-dynamic treatment of events

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1. Introduction

The Davidsonian revolution in semantics encouraged linguists to think of events as reified entities. In his discussion of sentences like that in (1), Davidson proposes that there is something 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.

Events are as real as individuals in that they can be observed, have spatial location, have temporal location, and be referred to with pronouns.

Neo-Davidsonian analysts saw a way to extend Davidson's proposal to characterize semantic subcomponents of predicates like theta roles, extracting core arguments from the main predicate and introducing them via two-place predicates such as Agent (x, e), 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.). This perspective eventually combined nicely with proposals emerging from the study of the internal structure of events, in which a consensus emerged that certain events — Vendlerian Accomplishments, at least — were composed of two sub-events, chained together in a causal relationship; *John opened the door* has a causing sub-event e_1 , and a result sub-event e_2 . The Neo-Davidsonian proposal allowed a straightforward expression of the insight that the agent *John* is the Agent of only the first, causing, sub-event, e_1 ; this event then is chained with e_2 , of which the Theme is predicated. The resulting picture, then, is one in which the Agent role is not predicated of the whole event, but only the first, causal event in a chain which in its entirety denotes an Accomplishment (Pustejovsky (1995), Ramchand (2008), Higginbotham (2000)).

This separation of e_1 and e_2 might appear to be especially appropriate in cases where there is an Agent *doing* something (e_1) which would normally be the causing subevent of a second *happening* subevent, but the *happening* (e_2) is non-existent, or the wrong kind of happening. There are numerous cases in natural language where these notions of *doing* and *happening* split; in effect, these are cases where Brutus does something with the intention of killing Caesar, but Caesar does not end up dead. However, the framework as it stands merely stipulates the causation relationship between e_1 and e_2 , and does not provide any understanding of how e_1 might cause e_2 , or how e_2 might possibly fail to occur even in the presence of an apparently appropriate e_1 .

Our goal in this paper is to use the notion of *forces* to ground the relationship between cause and effect. Forces, in physical systems, act on objects and produce results, but they interact with each other in predictable and well-understood ways, such that the same force applied to the same object may produce a different, or even a null, result, depending on what other forces are active in the situation. We claim that implementing an abstract version of this notion in a semantic system can allow us to understand how an event can fail to result in the usual or expected outcome. The analysis we will develop treats forces as functions from situations (spatiotemporal arrangements of individuals along with their properties) to situations.

Below, we exhibit several cases in which an event fails to culminate in the normal or expected way. In these cases, the grammatical system exhibits sensitivity to the absence of the result, given the appropriate action, which the Neo-Davidsonian event-chaining approach does not provide a mechanism to express. Rather, it requires the addition of the notion of 'inertia worlds' to capture such effects. We will claim that the work done by inertia worlds in a Neo-Davidsonian framework is more properly incorporated into the representation of events themselves, and we will argue that forces can provide us with an appropriately straightforward representation.

2 Data

2.1 *Non-culminating accomplishments*

In many languages, the relationship between e_1 and e_2 in Accomplishment predicates is clearly defeasible. We exhibit several such cases below. In some of these languages, the distinction between entailing and merely implicating that e_2 occurs has a grammatical reflex, as in the Austronesian examples from Malagasy and Tagalog below; in others it is not grammatically marked, as in the Salish and Karachay-Balkar examples.

Malagasy has an agentive infix, *-an-*, which indicates the presence of an initiating event and an active Agent, but the resultant form does not entail successful completion of the caused event—it is implied, but defeasible, as described by Travis 2000, and illustrated in in (2a) below. If *-an-* is replaced by *-maha-*, on the other hand, the resultant event is entailed, as in (2b).

- (2) a. namory ny ankizy ny mpampianatra
 pst.*Agent*.meet the children the people
- ... nefa tsy nanana fotana izy.
 ...but neg pst.have time they.
 "The teachers gathered the children but they didn't have time."
 (Travis 2000: 172)

- b. nahavory ny ankizy ny mpampianatra
pst.*maha*.meet the children the people

#nefa tsy nanana fotana izy.

...but neg pst.have time they.

"The teachers gathered the children but they didn't have time."

(Travis 2000: 172)

Similarly, the neutral form of the verb in Tagalog does not entail completion, but rather merely implicates it (Dell 1987, Schachter & Otnes 1972); the completion can be explicitly contradicted.¹

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

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

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

Finally, Karachay-Balkar, a Turkic language spoken in Russia, also has non-culminating accomplishments:

1. 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.

- (6) kerim ešik-ni ac-xan-dì, alaj boša-ma-kan-dì.
 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)

In all of these cases, the agent *does* something but is unsuccessful in getting the intended result to *happen*. It is worth emphasizing that these neutral sentences, while not entailing completion, are not imperfectives or progressives; they do not, for instance, behave in discourse as though they were derived statives, and cannot be an answer to the question “What is/was happening?” (Matthewson, 2004). In fact, in Bar-El et al. 2005, the authors assume that the neutral form is perfective, lacking an overt marking for imperfectivity. We therefore assume it is inappropriate to treat them as containing, e.g., a null imperfective operator.

2.2 Frustratives

One especially striking example in which the intention and the result of the action diverge is in the case of so-called frustratives. Descriptively speaking, the morphemes that mark frustratives can have a range of related meanings, including intention to do something that is not realized, trying but failing, doing something in vain, a situation that does not develop as expected, or non-continuation of a state. These are the cases we will provide an analysis of as an illustration of the framework we will develop here. To our knowledge, the frustratives remain relatively underexplored (though see Copley 2005).

To take one example, the frustrative marker *-pana-* in Amahuaca, a Panoan language spoken in parts of Peru, can be used to express that one was going to do something but was foiled, as in (7), or that a situation did not turn out as expected, as in (8).²

- (7) Xau vuchi-pana-x-mun hun hovi hi-cain
 turtle look.for-FRUST-NOM-TH me rain do-NONSQ(DS)
 ca-yama-vahii-ha-hqui-nu.
 go-NEG-all.day-COMPL.PAST-ACT-DECL
 (Sparing-Chávez 2003: 5)
 ‘I was going to look for a turtle, but it rained and I did not go all day.’

2. Abbreviations: ACT = actuality aspect, COMPL = completed, DS = different subject, NONSQ = non=sequence, SQ = sequence, TH = theme, TR = transitive

- (8) Pacuu-cahan-pana-xon-mun hun jii poyan hachi-cu-hnu.
 fall-almost-FRUST-SQ(SS)TR-TH I tree branch grab -1PAST-DECL
 'I almost fell (from the tree), but I grabbed a branch.'
 (Sparing-Chávez 2003: 10)

The particular frustrative construction we will be interested in is the Tohono O'odham frustrative morpheme *cem* (Hale 1969, Devens 1972, Copley 2005), where it is particularly clear that the choice between the meanings in part depends on the viewpoint aspect of the sentence, as shown in (9a-c).³ The future is always expressed by means of the perfective⁴ auxiliary plus a future marker. *Cem* sentences are always interpreted as past tense; whether this fact follows from something in the meaning of *cem* or whether it is a pragmatic effect is not known.

- (9) a. Huan 'at o cem kukpi'ok g pualt.
 Juan aux-pf fut cem open det door
 'Juan tried to/was going to open the door.'
 (he tripped before he got there)
- b. Huan 'o cem kukpi'ok g pualt.
 Juan aux-impf cem open det door
 'Juan tried to open the door.'
 (he pulled but couldn't get it open)
- c. Huan 'at cem ku:pi'o g pualt.
 Juan aux-pf cem open det door
 'Juan opened the door in vain.'
 non-continuation: Juan got the door open but it didn't stay open
 unachieved-goal: The door's being open didn't have the desired effect
 (Copley 2005: 9)

What all of 9(a-c) have in common is that Juan *does something* with a certain goal in mind, but what *happens* is something else. *Cem* apparently expresses the notion that the forces that Juan has brought to bear on the situation are inadequate to produce the intended effect, and furthermore interacts with aspectual meanings to determine the particular nature of the inadequacy of Juan's effort. With stative predicates, with either an animate or an inanimate subject, *cem* provides a 'former state' reading: the state 'failed':

3. Tohono O'odham does not mark past tense, and has a perfective-imperfective-future system that we will refer to as "viewpoint aspect."

4. Hale (p.c.) suggested that this perfective auxiliary is a default auxiliary.

- (10) Cem 'añ ñ-na:tokc.
cem 1sg 1sg-ready
a. 'I was ready.'
(speaker: "I'm not ready anymore.") non-continuation
b. 'I was ready.'
(speaker: "I was ready, but you weren't there") unachieved-goal
(Copley 2005: 1)
- (11) Howij `o cem suam.
banana Aux cem yellow
'The banana was yellow (implication: it is no longer yellow).'

These data highlight the difficulty that Neo-Davidsonianism has with events that fail to culminate as expected. What is the status of the event (e_1) of which Juan is an agent? Whatever it is, it is not necessarily an event that causes e_2 in the actual world --- at least, in (9a) and (9b). Worse, in (9c), the event e_2 *does* happen in the actual world, but either the result state fails to hold (non-continuation), or some other intended effect fails to happen (unachieved-goal).⁵ What could account for this range of meanings?

2.3 An unsatisfying answer - inertia worlds and the progressive

There are two issues that an analysis of these data must address. The first issue, as we have been saying, is that *doing* (i.e., e_1) and the *happening* (i.e., e_2) are distinct; it is possible to have a *doing*, by means of which the agent intends a *happening*, without having a successful *happening*. The second issue is how to relate the denotation of the verb phrase to e_1 , e_2 , or both, depending on the particular form in question.

These issues are not limited to the data we have presented above; they have already been discussed extensively in the literature on progressives, in the context of the so-called imperfective paradox. Briefly, the imperfective paradox draws on the fact that (12) can be true even if Mary never finished the circle. But assuming that the meaning of the progressive "Mary is drawing a circle" must be related somehow to the meaning of "Mary draws a circle," if Mary never actually draws the circle, how can (12) be true? That is, if Mary *does* an e_1 , seemingly with the intent that she draw a circle (the denotation of the verb phrase) and with every likelihood of succeeding, but if a finished circle never exists, that is, if the e_2 *happening* never happens, how

5. A kind of parallel effect is set up in English with different focal intonations. "I was ready" implies a contrast set of other people, possibly including the addressee, who weren't ready, resulting in the implication that there was an unachieved goal. Similarly, I *was* ready indicates a contrast with other non-past times, including the speech time, implying I that the proposition of me-readiness no longer holds, i.e., that I am not ready anymore.

can e_1 be linked to the meaning of the verb phrase, given that "Mary draws a circle" requires the circle to be created?

(12) Mary was drawing a circle.

Dowty's (1977, 1979) answer to this question is to propose *inertia worlds*: possible continuations of the world in which in which nothing interrupts the event. So the truth of "Mary is drawing a circle" is indeed related to the truth of "Mary draws a circle," it's just that "Mary draws a circle" is true only in those possible continuations of the world in which nothing interrupts the event. The difficulty in making the analysis work is in specifying precisely how this set of continuations is computed, a project taken up by others (Vlach 1981, Landman 1992, Portner 1998, Cipria and Roberts 2000; also Szabó 2004 and Wulf 2009 for a pessimistic view of the enterprise).

It is easy to see how the idea of inertia worlds might be of use in accounting for the data presented in sections 2.1 and 2.2. The first issue is how to separate the *doing* and the *happening*: on an inertia world analysis, the agent does an e_1 , the result is an e_2 and there is a stipulated CAUSE relation between e_1 and e_2 . In the cases where these come apart, e_2 occurs only in the inertia worlds, very similar to the inertia world proposal for the progressive cases; one way to express the difference would be to say that with the imperfective, the actual world does not include the entire e_1 , while with non-culminating accomplishments, it does (though see Bar-el et al. 2005 for a slightly different proposal). It is also relatively clear how to relate the meaning of the verb phrase to e_1 and e_2 , in an inertia world framework: the agent's doing of e_1 is introduced in the denotation of the vP, and e_2 is what is characterized by the lower VP.

While the inertia world perspective can indeed account for the data above (see, e.g. Tatevosov 2007, Bar-el et al. 2005, Matthewson, 2004), we believe that it vastly undersells the importance of the causal relationships between events. Many events have natural endpoints, i.e., natural or normal results given a cause and no external disruption. In certain circumstances, however, an event can be disrupted from its normal course, and thereby fail to reach its natural endpoint. We believe that this fact is absolutely central, not peripheral, to the linguistic representation of events, and needs to be treated as such.

We propose that the best way to meet this need is to introduce the notion of a *force* into formal semantics, reifying the causal relationship between one situation and another. This move greatly simplifies semantic representations. The complexity that in an inertia world perspective resides in the semantic representation, in our force-based semantics resides in the model, and the model itself rests on the hypothesized cognitive representations of situations in the world, which are presumably independently necessary.

3. Towards a force-based semantics

So far we have presented two kinds of data whose key similarity lies in the fact that there is an e_1 and an e_2 where e_1 is expected or supposed to cause e_2 , but the expected e_2 does not occur. We turn now to the task of defining a force-based model that builds this state of affairs into the representations.

This task begins with deciding what forces are, and how, given our current purpose, to model them. We present the framework of causal chains of situations that comes out of this picture, and what this account means for branching time. In addition, we discuss how something like gravity might be represented and what this representation has to do with non-spatiotemporal forces. Finally, we give a brief account of how psychological forces such as intentions are to be understood, before moving on, in the subsequent section, to our analyses of the data from sections 2.1 through 2.3.

3.1 *Initial and final situations*

A situation consists of a domain of individuals represented with their (known or relevant) properties. A force is an input of energy into some initial situation. This energy is either generated by an animate entity, or it comes from the motion or properties of an inanimate object. The application of this energy changes the initial situation into a different situation, as long as 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 initial situation is the one where the cup is at rest and the final situation is the one where the cup is moving. The input of energy causes the change from the initial to the final situation. We take events (as opposed to states) to always involve such an input of energy.

Now 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.

In the case where the force is strong enough to make the cup move, we observed an initial situation (cup at rest) and a different final situation (cup in motion). On the other hand, in the case where the force is not strong enough to make the cup move, the observed initial situation (cup at rest) is the same as the observed final situation (cup still at rest). If we were to grease the bottom of the cup, and thereby reduce the force of friction acting on the cup, we could reduce it sufficiently such that the very same force of pushing would now allow the cup to move, so again the initial situation would be different from the final situation.

A force's observed final situation is thus contingent on the existence and strength of other forces opposing it. Since this is the case, it is not going to be useful for us to define any given force

based on its observed final situation; i.e., we don't want to say that intuitively “the same force” would be defined differently depending on whether the bottom of the cup was greased or not. In fact, much of the work we want forces to do (cf. the examples in sections 2.1 through 2.3) has to do with counterfactual final situations, those that would ordinarily have been expected to happen if some other force hadn't intervened. So we will base the definition of any particular force on the “*ceteris paribus* (‘all else being equal’) final situation”—the situation that would obtain in the case that is just like the actual case but in which there is no stronger external opposing force.

3.2 *Representing forces*

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 is the agent or causer. The direction is, in an abstract sense, towards the force's *ceteris paribus* final situation. Magnitude, as we have seen, is only important in relative terms. We will not have much to say about the vector representation of forces.

Forces can also be represented in a Montagovian semantics as functions⁶ from situations to situations, type $\langle s,s \rangle$, which we will abbreviate for convenience's sake as type f . Forces in the real world are taken as primitive in the sense that they are observable, but they are formally not primitive. The idea behind the $\langle s,s \rangle$ type, as before, 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; a single situation, according to the laws of naïve physics, which are, we will assume, deterministic. We will therefore treat a force as having a unique initial situation, which we will write as $\text{init}(f)$, and a unique *ceteris paribus* final situation, to be written as $\text{fin}(f)$.

While it is true that many different forces can combine to result in another force (or, in event-talk, that many different events can together cause another event), the idea here is that the causing situation will include all of the individuals and properties that give rise to the *net force* that results in the final situation. The net force itself is calculated in the cognitive system. This calculation is easy to understand for cases of forces whose effects are strictly spatiotemporal; in the free-body diagrams familiar to anyone who has taken an introductory course in physics, it is possible to sum the physical forces that act on a single object to compute the net force acting on that object. However, the notion of force summation which we are constructing here diverges

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

from the physical kind in that it must take into account the fact that energy inputs into a situation will not all necessarily be acting on the same object in the situation; indeed the causes and effects may not be purely spatiotemporal. Nonetheless, this more abstract kind of summation is no problem to do, as humans (and other animals) are very good at looking at a situation and deciding what will happen next if nothing intervenes, regardless of the types of forces involved (Heider and Simmel, 1944; Michotte, 1946/1963).⁷

3.3 Causal chains of situations

If the laws of naïve physics are deterministic, we may speak of causal chains of situations, with the net force of one situation resulting in a unique successor situation, namely $fin(f)$. But this point of view raises an urgent question: if the laws of naïve physics are deterministic, how can there be branching futures? This question is not only of concern to philosophers; it is of concern to linguists as well, since we need to be able to represent what might happen or (if things had turned out a little differently) what might have happened.

In the framework we are proposing, outcomes of fully-understood situations are indeed deterministic. However, situations may be incompletely represented, resulting in several different possible net forces, and therefore in several different potential outcome situations, i.e. in branching futures. There are (at least) three distinct ways that things may turn out differently due to incompletely represented situations, even given the deterministic nature of naïve physics. The representation of the initial situation may involve: underspecification of the magnitudes of relevant forces, incomplete knowledge of what the relevant forces in a situation are, and/or incomplete knowledge of the potential sources of forces in a situation. Any discrepancy in which forces are included in the calculation of the net force will result in a different net force.

First, we may not know the magnitude of the forces that are acting in a situation. For example, in the cup-pushing situation, we may not know that the tabletop has a rubberized surface, resulting in a greater frictional force than expected, counteracting the pushing force acting to move the cup. More generally, Barbey and Wolff (2007) have argued that a causal chain of forces can result in several different outcomes according to the magnitudes of the forces involved. Moreover, he argues, people are bad at assessing anything but the relative magnitudes of two

7. In a sense, we are proposing that the cognitive system treats the initial situation as the ‘object’ on which all forces act; a force on a cup in fact is a force that applies to the situation to result in another situation where the cup is located somewhere else. If this perspective is correct, it may provide some insight into the way our cognitive system represents such apparent ‘forces on objects’; no object can be represented in isolation; it always forms part of some situation, even if that situation is quite minimal. A force diagram containing just an object, with no external spatiotemporal frame of reference, makes no intuitive sense.

forces right in front of them, so this indeterminacy arises quite generally and increases with the length of the causal chain, despite the deterministic nature of causality in his model.⁸

The second way that branching can occur is if we do not know which forces are acting in a situation. For example, in a coin toss, we don't know exactly what forces are acting on the coin. If we did, we would be able to say confidently if it would come up heads or tails. One major source of unknown and unknowable forces in situations is the actions of animate entities. We assume that naïve psychology includes a form of free will; animate entities can choose to act on the world in whatever way they like. Based on what an animate entity inside the situation decides to do, there can be different outcomes from the same situation. In any situation with an animate entity in it, then, there is the potential for unknown forces to appear, producing variable outcomes.

The third way that branching can occur is if the speaker is mistaken about the entities that belong in the initial situation, i.e., mistaken about which situation will give rise to the next actual situation. For example, suppose a car is traveling smoothly along the highway, but runs over a tack, puncturing a tire and resulting in an accident. If in the initial situation you did not perceive the tack, the relevant initial situation is unknown, producing a branching effect. Alternatively, consider a case in which you look at a vase tipping over and you judge that it is about to fall to the ground and break. But then someone (who you hadn't noticed before) standing next to the vase suddenly catches it. The situation of the person catching the vase is not caused by the situation that includes only the falling vase; instead, it is caused by the situation including both the falling vase and the person making the decision to catch it. Since the laws of naïve physics are deterministic only to the extent that nothing external to the initial situation s intervenes, it makes sense that there may be a different outcome if something external to s *does* intervene.⁹

The choice of the initial situation s does a lot of work in this model. When a speaker makes a claim about what forces are in play, they have a specific starting situation in mind. In all of the cases discussed in this section, the unexpected outcome is the result of the observer's incorrect choice of s . The situation that actually determines what comes next is a different (larger) situation than s , call it s' . So the successor of s (call it s_1) does not actually occur; what occurs instead is the successor of s' (call it s'_1). We will call situations which are well-enough specified

8. This implies that the nature of the indeterminacy of the future may be epistemic, i.e., that there is a fact of the matter but we just don't know what it is (cf. McTaggart's (1908) B-theory of time). We do believe that there is a metaphysical difference between the past and the future in that the future hasn't happened yet (making us A-theorists, in McTaggart's terms), in part because of overwhelming grammatical evidence that there are temporal differences between metaphysical and epistemic modality (Werner, 2006, Condoravdi 2001, among many others). It is true that the nature of the indeterminacy is in general epistemic in the model, with the (important) exceptions of animate entities' whimsical choices and, presumably, quantum events. However, it is significant that in our model, what is not known is not the future, but the present.

9. We will return to this kind of case in our discussion of the imperfective paradox below.

to fully determine what comes next *efficacious*. Branching futures result when the initial situation is not efficacious.

3.4 Gravity, tendencies, and fields

In the spatiotemporal cases such as pushing on the cup, it is evident that there is an application of energy. But in what sense is there an application of energy in the case of the frictional force, which results from the effect of gravity on the cup? Or for that matter, if you hold the cup in the air and then let go of it, and it falls due to the force of gravity, where is the “application of energy”? There are two answers to this question: the ancient physics answer (represented here by Aristotle)¹⁰ and the modern physics answer.

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.”

In Talmy’s work (1988, 2000) on the linguistic reflexes of cognitive representations, he echoes this Aristotelian notion: “[i]n 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). Modern physics has done away with this tendency 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 (this is Newton’s First Law of Motion).

The modern conception of gravity (without getting into quantum mechanics) is that of a vector field that interacts with objects in it. Any object in a gravitational field has a gravitational force on it that is calculated by using 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 perspectives both express the idea that where there is gravity and an object with mass, a force arises; this force results in an event if nothing stronger intervenes. In both perspectives

10. We take the ancients’ conception of physical forces to represent a sophisticated version of the ‘naive’ physical theory which the human mind is endowed with.

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 force that arises from the tendency in any particular situation, or the force that arises from the field acting on the particular object). A tendency or field, whatever its provenance, is therefore treated in any particular scenario as a force.

3.5 Beyond spatiotemporal effects

We are used to thinking of physical forces as contact forces that result in a change in the spatiotemporal properties of an object: where it is, whether it is moving or at rest, etc. In such cases, *init(f)* and *fin(f)* are situations that differ only in the the spatiotemporal properties of an object. But actually, any physical change could be represented as a function from one situation to another.¹¹ Consider a fruit ripening: *init(f)* includes the unripe fruit and *fin(f)* includes the ripe fruit. Insofar as ripening happens to all fruit unless it is chilled, eaten while it is still green, etc., this case is less like pushing a cup and more like gravity; fruit has a tendency to ripen.

We will collect tendencies such as that of unsupported objects to fall and that of fruit to ripen into something we will call the "normal field." Of course, forces don't exist until there are objects for them to act on. As we mentioned above in our discussion of gravity, in order for a field to give rise to a force, there must be an object of the appropriate kind for the force to act on. So the normal field can include the tendency of fruit to ripen, for instance, but unless there is a fruit in the initial situation, this force is not realized. The forces provided by the normal field should be assumed to combine with other forces in the initial situation in order to yield the final situation.

We mention the normal field here simply to signal that we are aware of the many forces that arise from dispositions, laws, and the like.¹² For the data we are considering in this paper, the normal field does not make an appearance in the semantics. Instead, the forces generated by the normal field are considered together with any other forces present in the situation, and the

11. This abstraction is already present in Aristotle's *Physics*, though Aristotle doesn't extend this analysis to verbs of creation and destruction (V:1).

12. A reviewer points out that many of the intervening situations in a causal chain involve forces which are crucial to the outcome, but not usually licit as causer subjects in sentences about that causal chain, giving the example in (i) to illustrate:

i) Booth/The gunshot/The bullet/#Gravity/#Friction/#The density of his clothes and flesh killed Lincoln. Languages may vary in which causers in the causal chain can be subjects (see, e.g. Folli 2002 on Italian vs. English), but one feature of the illegitimate subjects in (i) above is that the entities which they name are associated with forces in the normal field. We do not propose to try to provide an account of which causes in the chain are licensed as appropriate subjects in a given language or in general, that being properly within the purview of psychologists or philosophers studying causation. We note, however, that one relevant factor may be whether the speaker mentally includes a given force as part of the normal field or not.

cognitive system comes up with a net force of the situation -- the one that will lead to the *ceteris paribus* successor situation, if nothing external intervenes.¹³

We suspect that natural language does not need to refer to forces within a situation other than the net force, though there are some indications that language can take the net forces of two different situations and compare their magnitudes, as in the lexical item *prevent*, for example, where one force opposes another. Talmy (1988, 2000) presents many examples of this kind of agonist-antagonist opposition.

3.6 Physical and psychological forces

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 do an action. The idea that the conception of the physical world is co-opted for use in the psychological or psychosocial domain is present in Jackendoff (1987 et seq.) and Lakoff and Johnson (1999), among many others (see, e.g. , Bloom, Peterson and Garrett (1999) for a representative sample). Talmy (1988, 2000, a.o.) has extensively championed the view that force dynamics is the way to understand this link between the physical and the psychological. For example, while the sentence in (13a) is "force-dynamically neutral," the sentence in (13b) conveys that some other force, whether physical or psychosocial, prevents him from doing so if he wants to.

- (13) 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, *helped* her reach her destination, or *prevented* her from reaching her destination. The results exactly parallel the results he obtains in scenarios where inanimate objects are exerting forces on each other.

In future work, we will propose 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 intentions (Heim 1992, Portner 1997, eg.; see also in particular the notion of "teleological modality" as it pertains to anankastic conditionals, discussed in von Stechow & Iatridou 2004, Huitink, 2004, and von Stechow et al., 2004, among others). Rather than being functions from situations to situations, intentions will be functions from situations to properties of situations, or,

13. In generic sentences, however, we suspect that the normal field does occur in the semantics; to wit, that generics essentially assert that a particular force is in the normal field of the topic situation.

in some cases, to properties of forces. These intentional functions can have magnitude and can be used to calculate the net intentions of a situation (see also Copley 2008, 2009).

The interaction of intentions with a particular tendency in the normal field will provide our treatment of agency. In brief, we propose that individuals with desires 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 is subject to a particular psychological force—an individual with an intention or desire. If such an individual is in a situation which does not satisfy the desired property, then that individual is the source of forces which (*ceteris paribus*) will result in a final situation that does satisfy the desired property (or which contains a force which satisfies the desired property).

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 agency can be incorporated into the present framework, given the centrality of the Agent function in the neo-Davidsonian approach with which we contrast our proposal.¹⁴

4. Forces in action: Non-culminating accomplishments, progressives, and frustratives

In section 2, we introduced data indicating that languages can easily deal with the failure of a normal or expected event to occur; we also suggested that the causal relationship between events should be codified quite centrally in the semantics. In section 3 above, we gave some arguments outlining what the semantic model would look like if this causal relationship were in fact reified as the notion of force, a function from one situation to the situation that results if nothing else intervenes. The remainder of the paper presents accounts of both kinds of data discussed above in sections 2.1 through 2.3: non-culminating accomplishments in a number of languages, Tohono O'odham frustratives, and progressives.

A few formal details: we will assume that eventive *v*Ps are predicates of forces, so their type is $\langle f, t \rangle$ (that is, type $\langle \langle s, s \rangle, t \rangle$, since type *f* is shorthand for type $\langle s, s \rangle$); they will be represented by lowercase Greek letters π, ρ, \dots . Predicates of situations, also called propositions, are type $\langle s, t \rangle$ and are represented by lowercase Roman letters *p, q, \dots*. Stative predicates are also type $\langle s, t \rangle$. Situations will be referred to by the variables *s, s', s'', \dots*. It will be useful to refer to situations in a causal chain both with respect to the forces in that chain (i.e., a situation can be referred to as *init(f)* or *fin(f)*), as well as with respect to other situations in the causal chain; i.e., if *s* is a situation, *s*₁ is its (*ceteris paribus*) successor, and *s*₋₁ is its predecessor. The net force of a situation is *net(s)*, and all situations are assumed to have a net force.

14. This approach is fully compatible with a Fodorian view of intentional causation; see Fodor (1998: 59) for a critique of Agent as a primitive.

4.1 *Non-culminating accomplishments*

In culminating and non-culminating accomplishments alike, the net force of s is described by the vP . In languages or forms where accomplishments culminate, we propose that there is a presupposition that the topic situation s is efficacious; that is, that s is presupposed to proceed successfully, via the action of its net force, to its final situation without interference from outside of s . Since s is presupposed efficacious, it is entailed that the result situation of the net force of s actually occurs.

In languages or forms with non-culminating accomplishments, on the other hand, we propose that there is *no* presupposition that s is efficacious. Thus the result situation $\text{fin}(f)$ of the net force of s is not entailed to occur. On the other hand, there is still an implicature that the result situation $\text{fin}(f)$ holds. The reason is ultimately one of Gricean Quantity: $\text{fin}(f)$ is by definition the *ceteris paribus* successor of s , the situation that occurs if all else is equal. But if things aren't equal, i.e., if the circumstances are somehow unusual, the speaker would be expected to say so. So unless something specific is said to indicate that the result situation of the net force of s does not hold, it is implicated to hold. The difference between languages with and without culminating accomplishments, then, is a difference in the presuppositions attached to the vP ; such a purely semantic parameter would be unusual in the modern Minimalist generative framework. It is possible that this presupposition is attached to a particular morpholexical item in the relevant languages, rather like the presence vs. absence of definite determiners crosslinguistically; we leave the investigation of the nature of this parameter for future research.

While the details will have to be fleshed out,¹⁵ this is essentially the account we wish to propose. Significantly, there is no need for a modal operator to account for the non-culmination cases, as the absence of culmination follows from the absence of any presupposition of efficacy, rather than from any additional operator that removes the culmination entailment from the sentence.

4.2 *The progressive*

The meaning of the progressive falls out quite naturally from the proposed framework.¹⁶ Aspect, we assume, maps from predicates of forces to predicates of situations, so it is type $\langle\langle f, t \rangle, \langle s, t \rangle\rangle$ (this assumption is analogous to the common assumption that aspect maps from event predicates to temporal predicates; Klein 1994, Kratzer 1998). For the progressive, what we want is a denotation that takes a predicate of forces (π , the denotation of the vP), and a situation (s , the topic situation provided by tense), and says that the property π holds of the net force of s .

15. For example, one detail that will require attention is the difference between failed-attempt and partial-success readings of the non-culminating accomplishments (Tatevosov 2007).

16. Due to space considerations the discussion of the progressive will necessarily be brief; fuller justification and a formal development, including a more detailed discussion of the imperfective paradox and related problems (as discussed, for example, in Wulf 2009) will be given in future research.

(14) $\llbracket \text{progressive} \rrbracket = \lambda \pi \lambda s_0 . \pi(\text{net}(s_0))$

So, for example, if Mary 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 Mary, if all else is equal.

But *is* all else equal with the progressive? That is, does the progressive have an presupposition that the situation is efficacious, i.e., that it proceeds to its successor without external interference? Consider the contrast in (15) below:

- (15) a Mary was baking a cake, but she didn't finish it.
b ?Mary is baking a cake, but she won't finish it.

As far as (15a)--the classic imperfective paradox example--is concerned, the answer seems to be no. There is no presupposition that Mary finished the cake; if there were, the continuation in (15a) would be infelicitous. On the other hand, there's something strange about (15b).¹⁷ The difference between (15a) and (15b) is that in (15a), the situation of the first clause and the situation of the second clause can be different. In particular, the situation for the first clause is the s_0 from the perspective of the “topic time” (the time provided by tense, Klein 1994, etc.) at which Mary was messing around in the kitchen. Included in this situation is Mary, the kitchen, Mary's properties, and any forces generated by the normal field. However, something abnormal intervenes --- Mary gets bored, or the cake unexpectedly catches on fire, and so it turns out that s_0 is not efficacious. Instead, a larger situation s'_0 determined, in the end, what happened; its successor s'_1 came to pass, not the successor of s_0 (i.e., s_1). This interpretation is apparently unavailable for (15b), presumably because s_0 in both clauses has to be the same situation, i.e. the topic situation provided by present tense¹⁸ So in both clauses in (15b), the speaker has to pick the present situation that they think is efficacious, and it is apparently odd to change one's mind mid-sentence about which situation at the present time is the efficacious s_0 , though the acceptability of (15a) shows that one can change one's mind mid-sentence when talking about past situations.¹⁹ In any case, we may conclude that the progressive has an efficacy presupposition, but that when other things from outside s_0 in the history are seen to intervene, the speaker can no longer maintain that the old s_0 thought at the time to be efficacious really turned out to be efficacious in the end.^{20 21}

17. Cf. Copley 2008, 2009 for this point for futurate progressives (**The Red Sox are playing the Yankees tomorrow, but they won't*).

18. See Abusch 1997, Condoravdi 2003, and Copley 2009, e.g., for arguments that future *will* is present tense + an untensed modal *woll*.

19. It seems clear that the temporal location of s_0 is determined by tense, but exactly how situations and time are related in this framework is a question for further research.

20. Note that progressives are importantly distinct from non-culminating accomplishments: according to Matthewson 2004 and Bar-el et al. 2005, the latter are perfective; there is no ongoing reading at all. We

As Landman (1992) notes, the progressive creates an intensional context: if Mary is baking a cake, the cake does not (yet) exist and may never exist. The status of such “temporally opaque objects” (von Stechow, 2000) for us is that they are objects referred to in the *ceteris paribus* result situation of the Mary-bake-a-cake force--- a situation that may never come to pass. This status is not unlike the status of objects that exist only in inertia worlds. The status of the force itself in the proposed framework is a different question, but it too has an existence; the Mary-bake-a-cake force exists, as it is the net force of a current situation. Thus we avoid having to posit partial events like those proposed by Parsons (1989), and the empirical benefits of inertia worlds are retained.

4.3 *The O'odham frustrative*

Recall the frustrative data from Tohono O'odham:

- (9) a. Huan 'at o cem kukpi'ok g pualt.
 Juan aux-pf fut cem open det door
 'Juan tried to/was going to open the door.'
 (he tripped before he got there)
- b. Huan 'o cem kukpi'ok g pualt.
 Juan aux-impf cem open det door
 'Juan tried to open the door.'
 (he pulled but couldn't get it open)
- c. Huan 'at cem ku:pi'o g pualt.
 Juan aux-pf cem open det door
 'Juan opened the door in vain.'
 non-continuation: Juan got the door open but it didn't stay open
 unachieved-goal: The door's being open didn't have the desired effect
 (Copley 2005: 9)

take this to mean that perfectives, at least in the languages under discussion, convey that the force was already done applying at the past topic time (see also our analysis of O'odham perfective, below). In addition, as we argued above, non-culminating accomplishments lack an efficacy presupposition, while progressives have one.

21. The issue of causal pre-emption (see Lewis, 2004 and references therein) is connected to the treatment of the progressive here; if cause A is producing a force which will *ceteris paribus* result in situation *s*, but cause B intervenes and itself produces situation *s*, we assume that the *ceteris paribus* condition assumed by a speaker reporting a progressive form of cause A turned out to be violated by the intervention of cause B -- that is, the speaker was describing a situation which turned out not to be efficacious, though in the absence of the external intervention of cause B, it would have been.

Note that (9c) is different from (9a) and (9b) in that in (9c), the force applied to open the door is actually successful, it's the staying open, or being open for some reason, that fails. There are two readings of (9c): one on which the non-continuation of the result state is entailed, and one on which another goal or intention is not realized.

These same two readings -- non-continuation and unachieved goal -- are available for non-result states as well, as was shown above in (10):

- (10) Cem 'añ ñ-na:tokc.
cem 1sg 1sg-ready
non-continuation: 'I was ready but now I'm no longer ready.'
unachieved-goal: 'I was ready but you weren't there.'
(Copley 2005: 1)

The frustrative morpheme *cem* is in a different place in the word order in (9) and (10), which raises the question of whether *cem* has the same scope when it occurs with statives as it does when it occurs in eventives. Since Tohono O'odham has quite (albeit not entirely) free word-order,²² there is a limit to the syntactic information that can be drawn from the word order facts. The semantics, on the other hand, is more forthcoming. The existence of two similar readings for each of (9c) and (10) seems to indicate that *cem* bears the same relationship to the result state in (9c) as it does to the state in (10). We can also see that *cem* scopes over aspect, because aspect seems to apply directly to the verb phrase; the failure happens at a different point in the action in (9a-c) depending on the aspect.

Following Copley (2005) we take the assertion of a *cem* sentence to be the same as the assertion of the corresponding non-*cem* sentence; the only contribution of *cem* is a presupposition. Copley proposes that the presupposition *cem* contributes is that the actual world is not an inertia world. We will express our analogous, force-theoretic presupposition thusly: s_1 (the *ceteris paribus* successor of s_0 , the topic situation) did not happen; or equivalently, s_0 is not efficacious.

Since it is the interaction between *cem* and aspect that produces the variation in (9) and (10), we will give denotations of the aspectual morphemes in O'odham that will produce the desired denotations when combined with the presupposition of *cem*: i.e., denotations in which either the force was not applied, as in (9a), the force was applied but the s_1 did not occur, as in (9b), or the force was applied, and s'_1 occurred but s_2 , the expected successor to the predicted s_1 did not occur, as in (9c).

We will consider each of the three O'odham aspects in turn.

²² See M. Smith 2004 and references therein for discussion of syntax in the closely related language Akimel O'odham (Pima).

The prospective aspect²³ takes a predicate of forces (π , the denotation of the νP), and a situation (s , the topic situation provided by tense), and says that π is true of the net force of some situation in the causal chain proceeding from s_0 (recall that $s_1, s_2, s_3, \dots s_n$ are in the chain of situations that follow from s_0).

$$(16) \quad \llbracket \text{prospective} \rrbracket = \lambda \pi \lambda s_0 . \exists n: \pi(\text{net}(s_n))$$

For the imperfective, we use the same denotation as the progressive above,²⁴ which takes a predicate of forces (π , the denotation of the νP), and a situation (s , the topic situation provided by tense), and says that the property π holds of the net force of s .

$$(17) \quad \llbracket \text{imperfective} \rrbracket = \lambda \pi \lambda s_0 . \pi(\text{net}(s_0))$$

That is, a force with the property π is the net force in the topic situation, and if all else is equal and nothing external interferes, s_1 will result. For example, $\llbracket \text{imperfective} \rrbracket (\llbracket \text{Juan open the door} \rrbracket)(s_0)$ will say that the net force of s_0 is the force of Juan opening the door; if nothing intervenes, the door will subsequently be open.

Finally, we will treat perfective aspect as signaling that the resultant state of some force holds as of the topic time. Because s_{-1} is in effect shorthand for “a situation in the causal chain preceding s_0 ,” we permit, for the purposes of the current discussion, the binding of s_{-1} in the denotation below with λs_0 .

$$(18) \quad \llbracket \text{perfective} \rrbracket = \lambda \pi \lambda s_0 . \pi(\text{net}(s_{-1}))$$

The denotation for perfective aspect takes a predicate of forces (π , the denotation of the νP), and a situation (s_0 , the topic situation), and says that the predicate of forces π is the net force of s_{-1} --- that is to say, π is true of the force that caused s_0 , the topic situation.

Now we will show how the interaction of *cem* with aspect (or with the stative predicate, as in (10)) results in the correct denotations for the O'odham frustrative data. We will take each aspect in turn, first giving the denotation of the sentence without *cem* and then showing how the addition of the presupposition supplied by *cem* yields the correct denotation.

23. This form is normally (e.g. Zepeda (1983)) called a future; we call it an “aspect” here to emphasize the similarity in meaning to the imperfective and perfective. We call it “prospective” because it seems appropriate, not because it means *about to*. We suspect the latter makes a claim about s_1 : $\llbracket \text{about to} \rrbracket = \lambda \pi \lambda s_0 . \pi(\text{net}(s_1))$.

24. The O'odham imperfective aspect does not occur with stative predicates (Zepeda, 1983), and the denotation provided here reflects its progressive meaning, not any other meanings.

In prospective aspect sentences without *cem*, as in (19), the assertion is that there is a situation s_n in the causal chain proceeding from the topic situation s in which the net force is one described by the νP --- in the case of (9a-c), then, the force in s_n would be a Juan-open-the-door force.

(19) $\llbracket \text{prospective} \rrbracket (\llbracket \text{Juan open the door} \rrbracket) = \lambda s_0 . \exists n: \llbracket \text{Juan open the door} \rrbracket (\text{net}(s_n))$

Adding *cem* to this sentence adds the presupposition that s is not efficacious; that is, that s did not proceed without interference. Thus the immediate successor of s_0 , namely, s_1 didn't happen.²⁵ Therefore s_n didn't happen either, so Juan didn't even get to the door. This is indeed the correct meaning for (9a).

In the case of the imperfective, the sentence without *cem* says that the net force in s , the topic situation, is described by the νP . In (20), for instance, the net force in s is a Juan-open-the-door force.

(20) $\llbracket \text{imperfective} \rrbracket (\llbracket \text{Juan open the door} \rrbracket) = \lambda s_0 . \llbracket \text{Juan open the door} \rrbracket (\text{net}(s_0))$

If we add *cem* to the imperfective sentence, we add the presupposition is that s_0 is not efficacious; therefore s_1 didn't happen. This correctly entails that the force was applied in s_0 without successfully causing s_1 .

Perfective sentences, we proposed, assert that the νP characterizes the net force of s_{-1} , the immediate predecessor situation of s_0 . The final or resulting situation of the net force of s_{-1} thus holds in s_0 , the topic situation.²⁶

(21) $\llbracket \text{perfective} \rrbracket (\llbracket \text{Juan open the door} \rrbracket) = \lambda s_0 . \llbracket \text{Juan open the door} \rrbracket (\text{net}(s_{-1}))$

So in the perfective case, the result state holds of the topic situation s . We might compare (18) to a lexical stative, which we treat as a property of situations.

(22) $\text{stative} : \lambda s_0 . \llbracket \text{I ready} \rrbracket (s_0)$

In both cases, a property is asserted to hold of a situation. This is appropriate because when *cem* is added, in both cases, on both the non-continuation reading and the unachieved-goal reading alike, the property actually does hold at the past topic situation s : the door was open, the speaker was ready.

25. Recall that the topic situation s_0 has a net force which *ceteris paribus* will result in s_1 . But when s_0 is not efficacious, *ceteris* is not *paribus*.

26. One might think that an efficacy presupposition concerning s_{-1} would be needed to entail that the outcome that occurred was indeed s_0 . However, since s_{-1} is defined as the immediate cause of s_0 , in this case, efficacy follows.

Now, the *cem* presupposition is that s_0 is not efficacious, so s_1 didn't happen. But what exactly could be going on in s_0 , besides the door being open or the speaker being ready?

Suppose that s_0 is a minimal situation (i.e., the smallest situation in which the predicate of situations holds). So it is a situation in which there is a door and it is open (as a result of the Juan-open-the-door force) and there is nothing else, no extra individuals or forces. (Analogously, in the lexical stative example, there is the speaker and she is ready and there is nothing else.) In that case there is a zero net force in s_0 . If there is a zero net force in s , that means that s_0 , the *ceteris paribus* successor to s_0 , is identical to s_0 . But since the presupposition of *cem* is that s is not efficacious, s_1 is presupposed not to happen. That means that something external to s_0 intervened to prevent s_1 from occurring. I.e., since s_1 would have been identical to s_0 , if s_0 were efficacious, something must have happened to close the door or make the speaker unready. This case is the non-continuation reading of perfective and stative *cem* sentences.

Suppose instead that s_0 is *not* the minimal situation in which the state holds. So in s_0 , the door is open or the speaker is ready, but something else is going on, creating a non-zero net force that causes a *ceteris paribus* successor s_1 different from s_0 . But by the *cem* presupposition, s_1 doesn't happen. What is the non-zero net force in s_0 ? It could be anything; presumably a principle of relevance governs how the hearer accommodates the existence of this force. Inferring the existence of an expected effect for the state in question is one appropriate accommodation; in that case, *cem* expresses the non-occurrence of the expected effect.²⁷ This case is the unachieved-goal reading of perfective and stative *cem* sentences.

Given that these two readings arise with both perfective and stative *cem* sentences, the question then arises of whether the theory correctly predicts that imperfective and prospective *cem* sentences do not get two readings. It turns out that the theory does correctly make this prediction. In the imperfective and prospective cases, the result situation of the force is in the future with respect to the time of the topic situation; *cem* therefore merely asserts that the causal chain from the topic situation to the result situation has been interrupted. In the perfective and stative cases, on the other hand, the content of the vP is itself predicated of the topic situation, so an interpretation in which *cem* interrupts the causal chain *on the way to the result state* is not available. Instead, *cem* does its interruption after the (result) situation. In that case we have to accommodate a different kind of interruption, and it turns out there are two ways to do that. In the imperfective and prospective cases, accommodation, because unnecessary for interpretation, does not occur.

27. One could wonder why the expected effect inferred so often has to do with an external purpose for the state; in the case of (10), where the subject (a banana) of the state is inanimate, it seems that the potential for an expected-effect reading is absent, as the only translation given has the non-continuation reading. We leave the connection between animacy and the inferral of purpose for future work.

5 Conclusions and consequences

Above, we have proposed to reify *forces* in the semantic ontology, as functions from situations to situations, arguing that this move provides a natural approach to phenomena in event semantics in which subevents in a causal chain come to be disconnected in one way or another. We have illustrated the application of these ideas in the analysis of three cases which would otherwise require possible world semantics: non-culminating accomplishments, the progressive, and the O'dham frustrative particle *cem*.

We can think of three major advantages to our approach. The first is simply Occam's razor: we get a simpler semantics compared to the event-based framework for these data. Instead of a tortuous treatment of inertia using partial events or inertia worlds, we build inertia into the model through the use of physical and psychological forces, the *ceteris paribus* condition, and the normal field. Similarly, as pointed out by a reviewer, we don't need an invisible operator to cope with the intensional nature of object NPs in non-culminating accomplishments.

The second advantage of our approach has to do with how arguments of the verb are composed in syntax. Although we have not discussed argument structure in this paper, the particulars of the force-situation framework suggest that it is more straightforwardly compositional than is the event-based framework. In the latter, the constituents denoting subevents are related to each other by means of a stipulated "CAUSE" interpretive relation, imposed when a type mismatch is detected between the event-denoting subparts of the vP. In the force-situation framework, however, all components of the vP are composed via function application, just as other nodes in the structure are; the lower VP in *John opened the door*, for example, which we take to be a small clause [the door open] with denotation $\langle s, t \rangle$, is selected by a v° head of type $\langle st, \langle e, ft \rangle \rangle$, such that the $\langle s, t \rangle$ predicate denoted by the VP is interpreted as the final state of the force introduced by the v° head.²⁸

The third advantage is conceptual. The force-situation framework could clarify the interface with the cognitive system, since its ontology -- situations as spatiotemporal arrangements of individuals with the forces on them -- may be preferable to that of the event-based framework with its concatenated events that somehow cause one another. It is also likely preferable to treatments of situations as partial worlds within the framework of situation semantics (Barwise and Perry 1981, Kratzer 1989, 1990/2009, Portner 1997), since it is not at all clear how to make cognitively plausible sense out of possible worlds. On the other hand, we see no reason why many of the advantages of situation semantics (such as, for example, the use of situations as arguments of quantification in modals, Kratzer 2009) could not be done with our situations.

28. See Copley and Harley (in prep) for a full exposition.

We feel that the framework has introduced useful new ways of conceptualizing the natural course of events. In particular, the notion of ‘efficacy,’ which holds of a situation that successfully proceeds via its net force to its *ceteris paribus* successor situation, is a key concept in simplifying the ontology. Similarly, the normal field may provide an important tool to help understand the nature of agency, allowing us to derive the notion ‘Agent’ from an interaction between a force in the normal field (the Law of Rational Action) and independently necessary properties of intentional beings such as desires and intentions

Of course it remains to be seen how the force-situation framework deals with other data; we think that the analyses we have given in this paper show that the framework indeed merits further development. Among the future avenues of research that we envision are a detailed account of argument structure in this framework, including the notion of agency; the semantics of aspect, modals and conditionals, in which the concept of the causal chain is expected to be of use, especially for anakastic conditionals (von Fintel and Iatridou, 2004; Huitnik, 2004; von Stechow et al., 2004); and an expansion of the framework to account for informational states, making connections to Discourse Representational Theory (Kamp 1981, Kamp & Reyle 1993) and dynamic semantics (Heim 1982, Groenendijk, J. and M. Stokhof 1991, Beaver 2001).

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