The Lexical Semantics of Extent Verbs

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January 25, 2009

1 Introduction

[1]

Consider the sentences in (1):

(1) a. The fog extended (from the pier to the point).
b. The crack widened (from the north tower to the gate.)
c. The storm front crossed the entire state of Colorado.
d. Snow covered the mountain (from the valley floor to the summit).

Sentences like (1a)-(1d) have attracted the attention of a number of authors (Jackendoff 1990, Matsumoto 1996, Talmy 1996, Gawron 2005). Each has both an event reading and a stative reading. For example, on what I'll call the *event reading* of sentence (1a), a body of fog beginning in the vicinity of the pier moves pointwards, and on the other, stative reading, which I'll call an *extent* reading, the mass of fog sits over the entire region between pier and point. The event reading entails movement. The extent reading entails extension, the occupation of a region of space. Similarly, there is a reading of (1b) describing a crack-widening event, as well as a reading describing the dimensions of the crack, increasing in width along an axis extending from the north tower to the gate; and readings of (c) and (d) describing movement events as well as readings describing the configuration of the storm front and the snow respectively.

It has been observed by a number of authors (Verkuyl 1972, Dowty 1979, Krifka 1989b, Jackendoff 1996, *inter alia*), that the aspectual nature of a clause, at least in the sense of the categories of accomplishment, activity, achievement, and state of Vendler (1957), is not a property directly inherited from verbs. For example, the boundedness or quantization of arguments may make a verb alternate between accomplishment and activity readings at the VP level:

(2) a. She drew the circle in under 10 seconds.

[1] I am grateful to Farrell Ackerman, Chris Barker, Daniel Büring, Chris Kennedy, Andy Kehler, and Rob Malouf for saying interesting things, sharing insights, asking good questions, and pointing out boners. This work also benefited from the questions and comments of audiences at UCSD and SALT who heard talks on early versions. Any remaining flaws are my own.

b. She drew circles for 20 minutes.

In other cases, the same alternation between accomplishment and activity may be observed without accompanying alternations in overt arguments:

(3) a. The river widened for hours.
b. The crack widened in minutes.

An abbreviated description of the analysis of Hay et al. (1999) (HKL) is that it tries to reduce the cases in (3) to cases like those (2) by positing a degree-of-change argument (sometimes surfacing as a direct argument, *widened 3 inches*, or in a *by*-phrase, *widened by 3 inches*), which may be either be covertly quantized or not. Thus the same underlying lexical representation may be associated with both accomplishment or activity readings.

At the same time the distinction between the static class (state) and the other three dynamic classes (activity, accomplishment, and achievement) has a somewhat different status. The aspectual alternations in (1) are alternations between dynamic (activity or accomplishment) readings and state readings. Under most lexical semantic accounts, no single lexical predicate is compatible with both kinds of readings. Thus, in cases like those in (1), the verb needs to be treated as lexically ambiguous, with some operator applying to the state meaning to derive the dynamic meaning. An example of such an account is that in Jackendoff (1990):

(4)

Extent	cover
Event	BECOME(cover)

What BECOME(cover) in (4) requires is there is a transition from a not-covered state to a covered state. The idea that a transition between two states is the essential feature distinguishing states from dynamic predicates goes back at least to Dowty's (1979) aspect calculus, which introduces the BECOME operator for just that purpose.[2]

Supporting this view is the fact that morphological alternations with exactly the semantics of transition captured by BECOME are widely attested cross-linguistically, including in English. Thus we have the English inchoative alternation, in which an adjective is related to a verb; typical examples are given in (5):

(5)

Adj	Verb	Adj	Verb
wide	widen	large	enlarge
long	lengthen	full	fill
hot	heat	cool	cool

Although there are a number of examples of zero-derivation within the paradigm (*warm*, *cool*, *narrow*, *dry*, and so on), zero-derivation is not uncommon in English, and

[2]More generally, the idea of the BECOME operator as a component in lexical semantics goes back at least to Lakoff (1965). Dowty's contribution is to incorporate it into a systematic account of lexical aspect and to try to provide an explicit model theoretic definition.

the status of this alternation as a productive category-changing derivational process is uncontroversial.

Thus we have independent motivation for **aspect-changing operators** such as Jackendoff's BECOME operator so it is, at first blush, not unnatural to assume it is playing some role in a zero-derivation process in (1). However, there are a number of problems with this idea.

To start with, the same kind of ambiguity occurs with forms which, on the account just sketched, already contain a BECOME operator. Thus, the degree achievement verb *widen* in (1b), has both event and extent readings. Laying aside objections about what it would mean to apply a BECOME operator twice, the problem is that we have no semantics that would plausibly account for a stative reading for a form which already, as it were, incorporates a BECOME operator. I will lay out the objections to such an aspect-changing account in more systematic fashion below.

Here I wish to lay out an alternative which I will call an underspecification account. On the underspecification account, forms like *widen* have an underspecified aspectual nature: they can be either stative or not. Moreover, such forms are always like *widen*; that is, they are intrinsically dynamic predicates. This picture is as in (6):

(6)

<table>
<tr><td colspan="2">+ Dynamic</td><td>- Dynamic</td></tr>
<tr><td>- State</td><td colspan="2">+ State</td></tr>
</table>

So what I am saying about *widen* is that it is $[+\text{Dynamic}]$, meaning that it can be either $[+\text{State}]$ or $[-\text{State}]$,

The challenge, of course, is to make some semantic sense of the idea of dynamic statives. What makes sense of it is the following picture. To be dynamic means to describe a change and change may occur in either a spatial dimension or in a temporal dimension. When I say of an event property that it is a [+ State] property, I mean that it is static and homogeneous in time; if e has such a property, then temporal sub-events of e have the property. Predicates like *widen* are two-dimensional. That is, they have the unusual feature that they can denote properties that are spatially dynamic (they denote change in space), but static and homogeneous in time.

Now in order to make such a proposal plausible one has to be able to make clear what it is that makes a predicate two-dimensional in the way I say *widen* is. In what follows I will claim that it is a lexical property of certain predicates that they are **extent** predicates, that is, they can describe properties oriented by and located on a spatial axis. For dynamic predicates with extent readings, that spatial axis can become the **axis of change**, the axis along which change is measured. A two-demensional predicate, then, is one that can describe change along both a temporal and a spatial axis.

The starting point for such an analysis is that there is a class of predicates in English for which a contextually available spatial axis is semantically significant. I will call this class of predicates **extent predicates**. All the verbs in (1) are extent predicates. My operational definition of an extent predicate is this: An extent predicate accepts **extent path phrases**, that is, path phrases co-occurring with stative readings. This is shown for *widen* in (7), using Vendler's own test — incompatibility with the progressive — to demonstrate that the readings exhibited are stative.

(7)

Criterion	Example
Path phrases	The crack widened *from gate to north tower*
Extent reading	The crack *widened 5 inches in less than 100 yards*
Stative	The crack **was widening 5 inches* (extent reading)

Any predicate meeting this definition has what I call extent readings. Not all predicates with extent readings also have event readings:

(8) The bridge spans from the Lower East Side of Manhattan to Brooklyn.

But verbs like *span* seem to be rare. Most verbs with extent readings also have event readings. In any case the claim is that spatial axes are significant for extent predicates, whether they have event readings or not. To justify that claim is one of the central goals of this paper.

I want to argue first that, given this definition, the phenomenon of extent predicates is quite robust. I begin with degree achievements like *widen* in (1). Other axial degree acheivement verbs include:

(9) narrow, warm, cool, rise, fall, darken, lengthen, shorten, dim, grow, smooth, thicken, swell, shrink

as well as all color/light degree achievements:

(10) redden, whiten, bleach,brighten, darken, pinken, lighten

I will call these **extent degree achievements**. All of these verbs share the property that they are degreeable like the degreeable states they are related to, and in some cases the degree argument may be overtly filled by a measure phrase:

(11) a. The river widened 10 feet.
b. The river widens more than the road.

They also accept path phrases on their extent readings:

(12) a. The sky brightened at the horizon.
b. The bridge narrowed from the midpoint of the canyon on.
c. The road rose from the canyon floor to the ridge.

There seems to be no special connection betwen extent readings and deadjectival verbs. Extent readings are quite at home with degreeable verbs that are not deadjectival and describe location-sensitive properties.

(13) a. His leg swelled noticeably just above the ankle (adjectival form *swollen* is deverbal).

b. The sheet crumpled up below his knee, exposing his ankle.

Another large class of extent predicates can be found among the so-called **path-shape** verbs of FrameNet (Fillmore and Baker 2000). This class includes *cross* illustrated in (1c). Although (1c) is carefully constructed so as to be ambiguous, this is a class of verbs for which it is sometimes difficult to produce ambiguous sentences, because there is a shift in selectional requirements between event and extent readings:

(14) a. The road crossed the valley. [Extent reading]
b. The truck crossed the valley. [Event reading]
c. The road zigzagged up the hill. [Extent reading]
d. The halfback zigzagged to the goal line. [Event reading]

Here sentence (a) describes a spatial configuration, sentence (b) a motion event. The other verbs in the Framenet frame all exhibit the same kind of event/extent uses, with similar shifts in selectional requirements:

(15) angle, bear, bend, climb, crest, crisscross, cross, curl, descend, dip, dive, drop, edge, emerge, enter, exit, leave, meander, mount, plummet, reach, rise, round, skirt, slant, snake, swerve, swing, traverse, undulate, veer, weave, wind, zigzag

The existence of selectional shifts like those in (14) might tempt one to analyze these cases via some kind of lexical rule, either as a standard zero-derivation, or as a **rule of polysemy** (Nunberg and Zaenen 1992), like that which relates meat uses to animal uses for a class of Anglo-Saxon meat/game words like *chicken*, *turkey*, and *trout*.

I will argue that the selectional shifts between event and extent readings for path shape verbs may be independently explained by the interactions of general properties of extent predicates.

A rough outline of the acount goes as follows. The semantic constancy of path-shape verbs is captured by the class-name: The predicate ascribes a particular shape to a path. On the event reading that is the shape of a path traced out in time, on the extent reading it is the shape of a path realized by a static spatial configuration. Thus, with respect to extent readings, what is going on here is fundamentally the same as what is going on with extent predicates like *extend*, which do not show any selection shifts between event and extent readings. The figure in an extent reading is always represented as *extended* over the entire path, and the property being attributed is always to a spatially defined configuration of the figure's parts. It follows that figures that cannot be extended in the required configuration (such as halfbacks) are disallowed on extent readings.

The real question is: Whence the selectional shift? Why do verbs like *cross* and *zigzag* allow non-extended figures like halfbacks on their event readings? Putting this another way: What distinguishes verbs like *zigzag*, which allow non-extended figures, from verbs like *extend* which do not? The plausible answer is that it is *extend* which is the marked case. Most motion verbs depict *displacement*, advancement to a new location accompanied by removal from an old one, allowing rigid figures like halfbacks (I will call this **incremental motion**). But it is an idiosyncratic property of verbs like *extend* and *surround* that the event reading only describes what I will call *spreading movement*: as location $i + 1$ is occupied location i continues to be occupied. Thus rigid figures like halfbacks are disallowed.

In Section 4, I will propose a formal account of these observations based on scalar semantics for extent verbs. Motion verbs like *cross* will be associated with distance scales, which be required to increase over time on event readings. This will entail motion (but will not distinguish displacement from spreading motion). The restriction to spreading motion for verbs like *extend* will be captured because they will be lexically associated with an *extent* scale, so the length of the figure will be required to be increasing over time on event readings.

I will call the larger class of predicates lexically selecting path-phrases, including motion verbs, **axial predicates**. Not all axial verbs are extent predicates, because their path phrases often resist extent readings. One property that precludes extent readings is any variety of obligatory agentivity. To repeat an example used on the Framenet site in defining path-shape verbs, *snake* and *slither* differ in whether extent readings are possible, because *slither* describes the manner of motion of an animate moving subject:

(16) a. The trail snaked up the hill.
b. # The trail slithered up the hill.

Having provided some evidence of the productivity of the phenomenon, I turn now to the semantic analysis of extent predicates. Building on the analysis of Hay et al. (1999), Gawron (2005) proposes an analysis of extent predicates assuming they are gradable properties. That is, each dynamic predicate is associated with a scale defining the degree of change in the event. More specifically, the denotation of each verb is an *eventuality function*, a function from eventualities to degrees. The eventuality function for *widen* is a function to distances, and for *brighten,* a function to degrees of brightness. The value of the function for a widening event e is the change of width that occurs in the course of e; the value for *brighten*, the change in the degree of brightness. The key assumption required to account for event/extent ambiguities is that all extent predicates make use of a spatial axis I will call the context axis. An immediate consequence is that the co-occurrence of path-phrase modifiers with extent readings, noted by Jackendoff (1990), is explained. Path phrase modifiers arise because they are key linguistic devices for defining and orienting spatial axes. The second consequence is that extent readings are accounted for as cases in which the eventuality function evaluates change along a spatial axis. Call this idea, the idea that extent readings are cases in which a gradable event property is evaluated with respect to a spatial axis, the GHKL analysis.

The benefit of introducing a spatial axis is that it introduces a second dimension. Gradable predicates that are uncontroversially stative can still describe change. We already saw evidence for this in (7), when we applied the Vendlerian test for an accomplishment in an extent reading of *widen*. The GHKL analysis predicts that we should see both spatial accomplishments and spatial activities. We can in fact find both with extent readings of *widen*:

(17) a. The crack widened nearly half an inch in ten meters.
b. The crack widened for 100 yards.

Call this argument for the GHKL analysis, the existence of spatial analogues of Vendlerian accomplishments and activities, argument one.

The analysis of *widen* proposed here is aspectually neutral. That is, there is no aspect-changing operator like BECOME relating event and extent readings; the basic claim of such an account is that both readings are given by a single dynamic predicate. Therefore, both readings should exhibit the same aspectual nature, modulo the axis along which change is measured. And this appears to be correct. Parallel to the spatial activity and accomplishment examples we see in (17), we have the kind of temporal actity and accomplishment examples noted in Hay et al. (1999):

(18) a. The crack widened five inches in five minutes.
b. The crack widened for several hours.

As pointed out above, the morphology of *widen* is significant. Forms like *widen* already contain a suffix *-en* known to make dynamic predicates, yet stative extent readings are possible.

(19) Morphology: *widen* = *wide* + *-en*

(a) The crack widened from the north gate to the tower.
(b) Event: An event occurred in which the width of a crack increased over a span ranging from the north gate to the tower.
(c) Extent: The width of the crack was greater near the tower than near the north gate.

Obviously, an account on which adding *-en* creates a single dynamic predicate responsible for both readings would economically capture the facts. Call the morphological evidence that *widen* is dynamic argument two.

A third argument for the dynamic nature of extent readings is their compatibility with adverbial modifiers like *gradually*. Sentence (20) has both event and extent readings:

(20) The crack gradually widened from the north gate to the tower.

The meaning of the extent reading is that the increase in width in moving from the north gate to the tower is gradual. Note also that the directionality imposed by the path-phrases on the extent reading has a truth-conditional effect: The crack must be wider at the tower end.[3]

Finally, there is a simple descriptive problem with the primary alternative to an underspecification account: an account by aspect-changing operator along the lines of Jackendoff's. Consider for example trying to relate the event reading of *widen* to the extent reading via INCREASE. It is simply wrong (truth-conditionally) to say that the event reading of *widen* means *come to be an x that increases in spatial widening*. An X that widens spatially must be wider in one place than in another, but at the end of a temporal widening event, a crack may be the same width everywhere. This point, then, carries over to BECOME. The final state of a temporal widening event does not have

[3]This directionality actually goes away with the event reading, a detail that will fall out from the semantic underspecification analysis given below.

to be one that counts as a spatial widening event. The two readings simply stand in a different semantic relation.

Summarizing, we have now given four arguments for an underspecification account for *widen*.

(21)
1. Vendler class tests;
2. Graduality;
3. Morphology and the contrasting stative readings of *wide* and *widen*;
4. Semantic relation (the event and extent readings do not stand in a relation describable either by INCREASE or BECOME).

Although I will focus on the issue of acounting for event extent ambiguities, the real research question of this paper is whether the class of extent predicates is linguistically significant. Does it make sense to identify a class of predicates (in particular, verbs) for which an orienting spatial axis is obligatory? The underspecification analysis of event/extent ambiguities — if correct — is strong evidence of the linguistic reality of such axes, but as we shall see, the same arguments do not carry over to the other verbs in (1). Thus, the case for spatial axes for these verbs is a little more complicated.

Consider now extending the underspecification account to two of the other verbs in (1), *cover* and *extend* (Henceforth, I will just discuss *extend*; the facts for *cover* are analogous). To account for the extent readings along them same lines we accounted for *widen* would mean assuming some eventuality function EXT, which returned degrees of extension (distances). Combining this with INCREASE would yield a dynamic (activity/accomplishment) predicate, and evaluating INCREASE along spatial and temporal axes would yield extent and event readings respectively.

Note first of all that *extend* does not show the morphological evidence that was so compelling for *widen*. There is no adjective obviously related to *extend* and no morpheme that combines with it to yield a dynamic verb.

Suppose, then, that *extend* is two-dimensional (spatially and temporally dynamic), that is, spatially dynamic without being related to a stative predicate by an INCREASE operator. That is, it is like *widen* but without a related stative form analogous to *wide*. There were basically two direct semantic arguments that *widen* was spatially dynamic, Vendlerian tests like those in (17) and graduality of extent readings as in (20). Both fail for *extend*. Consider, first, the Vendlerian test:

(22) # Because of its relentless switchbacks, the trail extended 5 miles in just 2 miles as the crow flies.

The construction of acceptable spatial accomplishment test sentences appears impossible with the verb *extend*. Next consider graduality:

(23) The fog gradually extended 10 miles into the woods. (event reading only)

Sentence (23) lacks an extent reading, Signficantly, (23) does have an event reading, so we cannot simply say *extending* is an end-of-scale state incompatible with graduality. The dynamic temporal predicate is compatible with *gradually* , while its spatial analogue, if there is one, is not. Why?

This is particularly troubling because of the following generalization: The adverb *gradually* seems to always be compatible with clear degree achievements: *cool gradually, warm gradually, rise gradually, lengthen gradually, enlarge gradually*, and so on. In the case of *widen* we have seen this generalization extend in to the domain of spatial aspect. This can be captured simply by saying that *gradually* combines with any verb whose denotation is defined in terms of the INCREASE operator. If you can increase in X-ness, then you can gradually increase in X-ness. Let us distinguish between increase along the spatial dimension, denoting the operator INCREASE_S, and increase along the temporal dimension, INCREASE_T. Graduality with event readings seems to be a point in favor of an analysis of the event reading via INCREASE_T; however, the absence of graduality with extent readings seems to weigh heavily against any analysis of extent readings with *extend* via INCREASE_S.

Finally the semantic relation argument fails for *extend* and *cover* as well. That is, it is possible, semantically, to analyze both verbs as their own inchoatives. The event reading of *extend* really does mean *undergo an increase (in time) in degree of extendedness*, and the event reading of *cover* really does mean *undergo an increase in the degree of coveredness*. On the other hand, *widen* clearly does **not** have event and extent readings relatable by INCREASE.

The semantic relation argument also fails for the path-shape verb *cross*, the last of the verbs in (1): *cross* really does mean *undergo an increase in the degree of crossing*. This is demonstrated in some detail in Section 4. However, The case of verb *cross* diverges interestingly from those *cover* and *extend*, because evidence for a spatially dynamic predicate exists.

(24) a. The trail crossed the ridge in 20 wildly zigzagging miles.
b. Following the many bends of the river, the trail gradually crossed the valley.

Example (24a) accomplishment and activity tests, modulo spatial axes, work for *cross*. Example (24b) shows that the adverb *gradually* combines with *cross* on an extent reading.

There is of course an analysis which will account for *cover*, *extend*, and *cross* uniformly. This is the account by aspect-changing operator already sketched in (4) and implemented in Jackendoff (1990). This account acknowledges the semantic relation between event and extent readings, and says the event/extent ambiguities are simply ordinary inchoative alternations. Using the INCREASE operator of the HKL analysis (rather than Jackendoff's BECOME operator), the analysis of *extend* would be:

(25) Aspect Changing analysis

(a) Event: $\text{INCREASE}_\text{T}(\text{extend}_T(e, \text{fog})) = d$
(b) Extent: $\text{extend}_T(\text{fog})) = d$

This account works for *extend* because the semantic relation argument failed for it: an event reading really can be represented as an increase in spatial extension. It works for *cover* and *cross* for the same reason.

However, if the aspect changing account is adopted for *cross*, there is an interesting consequence: The INCREASE operator must apply to a dynamic predicate, according to the tests in (24). This is not a contradiction, if one takes the two-dimensional semantics seriously. Let us distinguish between a gradable property that increases in time (with INCREASE_T as a component), and one that increases in space (with INCREASE_S as a component). I assume that INCREASE_T cannot combine with temporally dynamic properties, but there is no reason to assume the same for spatially dynamic properties. What the argument of INCREASE_T must be is a function that can sensibly take a value at a point in time; and a dynamic spatial function is such a function. That is, it makes sense to speak of the increase in crossing along a spatial axis S *at a moment in time*, and it makes sense to speak of that increase increasing between two separate moments in time. I will spell out the details below, but the desired formal property is clear: a spatially dynamic eventuality function may still be temporally stative.

So much for the main prerequisite of of (25): It is at least semantically coherent. But notice that even though English has lots of zero-derivation, (25) is still a strange idea, at least as a proposal for a large class of English verbs (*cover*, *extend*, *cross*, and all the other path-shape verbs). Although there exist zero-derived stative-inchoative pairs like [Adj *cool*] and [V *cool*], apart from these event-extent alternations, it is always the case that the stative member of the pair is an adjective and the dynamic member is a verb. That is, apart from the event/extent ambiguities we are trying to explain, there are no other instances of zero-derived inchoative pairs in which both members are verbs. This is despite the fact that there are clearly stative degreeable verbs in English, such as *weigh*. But *weigh* can not mean *come to weigh more*; it is not its own inchoative. Another way to put this is as follows: Evert case of an English verb that has both event and state readings admits the kind of stative path phrases that qualify it to be an extent verb.

In what follows, then, I develop an underspecification analysis for *widen* and an aspect changing analysis for the other three verbs. Such a picture raises several question about the motivatedness of obligatory spatial axes.

(26)
a. There is some motivation for axes in the case of extent predicates amenable to the underspecification account. But are spatial axes really motivated for any of the other predicates?
b. Why are the only English verbs that are their own inchoatives extent verbs?
c. The application of INCREASE_S is somewhat limited. It applies only in the case of degree achievements. Is this a stipulation, or is there an explanation for the limited applicability of this operator?

The answers to these three questions are related. Verbs and adjectives alike will have eventuality functions as their denotations. Eventuality functions can in turn be divided into event functions and state functions, as we will see below. All adjectives have state functions as their denotations and, as a default, verbs have event functions as their denotatons. However, the notions state and event functions are axis-relative. An eventuality function can be two-dimensional, and this means it can be a state function with respect to the temporal axis and an event function with respect to a spatial axis. I will argue that this is the case for *cover*, *extend* and *cross*. Thus, the answer to the first question in (26) is that understanding axis-relative constraints on verbs is crucial to understanding their aspectual nature. A potential answer to the second question in

(26) then opens up; the default denotation for an verb is an event function. For most verbs, this means they are not eligible to combine with INCREASE to become their own inchoatives. But, as just argued for *cross*, in the special case of two-dimensional verbs, where a verb denotation can be a state function with respect to time, it makes perfect sense for it to combine with $\text{INCREASE}_{\text{T}}$. Thus, given that the default verb is an event function on some axis, the only verbs that can be their own inchoatives are the verbs with an extra spatial dimension, that is, extent verbs.[4]

This still leaves the third question in (26). Is the restricted applicability of $\text{INCREASE}_{\text{S}}$ a stipulation? I will argue that there are significant constraints on the applicability of $\text{INCREASE}_{\text{S}}$ based on axis orientation, and that these explain the absence of spatial dynamic readings derived by $\text{INCREASE}_{\text{S}}$ for *cover*, *cross*, and *extend*. In fact these are the same constraints that help determine whether an eventuality function is a spatial state function or event function. In general, the existence of spatially dynamic readings will depend on axis orientation.

A few words on such axial constraints are in order, to set the stage. Whether an axis α is spatial or temporal, let us call the kind of eventuality function that can felicitously-combine with INCREASE_{α} α **state-functions**. Intuitively, for an eventuality function f to be a α state-function, means that it is meaningful for f to take values at points on α . A key claim of this paper is that whether f is an α state-function will depend on how α is oriented relative to the kind of change being measured, when α is spatial. As a consequence, predicates like *cover* are α state-functions for some spatial axes but not others. What is interesting is that the same kinds of axis-orientation constraints can be shown to apply to degree achievement verbs like *widen* and *lengthen*. Thus, there is a good deal more unity to extent predicates than might be thought. What really distinguishes *widen* from *cover* and *extend* is the measure properties of their default spatial axes.

I will argue for two kinds of axis constraints.

(27) a. Whether spatially dynamic readings arise; for example, *widen*, and *lengthen* vary between nondynamic and dynamic spatial properties depending on the orientation of the axis; and so can *cover*.

b. Whether paths are incremental themes can depend on axis orientation. If we take path as incremental theme as diagnostic of motion, this means whether a predicate is a motion predicate or not can depend on axis orientation.

To illustrate these ideas, consider the contrast between (28a) and (28b):

(28) (a) The cable widened 3 inches in the den.
(b) # The cable lengthened 3 inches in the den. [on extent reading]
(c) The skirt lengthened 3 inches in back.[Daniel Büring, pc]
(d) # The aperture widened from the edge of the door to six inches beyond it. [on extent reading]

[4] This means there is no explanation for why *weigh* isn't its own inchoative, since it is clearly stative, too. Nor as we will see, is there any explanation for why *full* is an adjective. So these become accidents on the proposed account, but accidents that are marked cases.

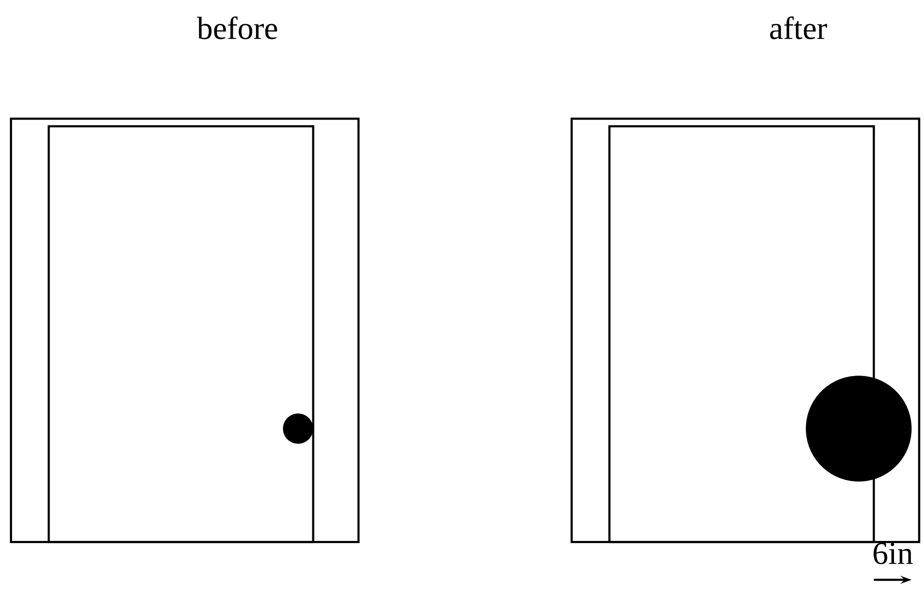


Figure 1: Aperture widening in (28d): μ_{X} where X = S.

Example (a) has a an extent reading meaning *the cable was 3 inches wider in the den than elsewhere*; but example (b) does not have a corresponding extent reading meaning *the cable was 3 inches longer in then den than elsewhere*. It might be thought that this is evidence that *lengthen* in contrast to *widen*, is not axial, but in fact, example (c), which has a felicitous extent reading, shows that this is not the case. Example (d) shows that we achieve the same effect with *widen*. Example (d) has the event reading shown with before and after pictures in Figure 1, where the dark circle represents the aperture, and the inner rectangle the door; like (b), (d) has no extent reading. For example, it cannot be used to describe the state depicted in the after-picture in Figure 1.

The description of the problem is this: For both *widen* and *lengthen*, an extent reading exploits two spatial axes, the axis along which the measurement takes place, **the measurement axis** (call it X), and the axis along which the measurement varies, **the axis of change** (call it S). In the infelicitous examples, X = S. Example (28b) is an attempt to use the canonical length axis of the cable for cable length (the axis perpendicular to circular cross-sections of the cable) simultaneously as the measurement axis and as the axis of change. This is infelicitous. Examples (28a) and (28c) remedy the problem because the measurement and change axes are independent. Example (28a) remedies the problem by changing the measurement axis; example (28c) remedies the problem because skirt length is measured on a vertical axis, and the axis of change is a front-to-back axis. Example (d) reintroduces the problem with *widen*. The natural axis of change is a horizontal radius of the circle, but this is also the only available axis of measurement.

What I will call a **measure function** can be defined in terms of a measurement axis X and a context axis S:

(29) $\mu_{\mathrm{X}} : \mathrm{S} \times \mathrm{I} \rightarrow \mathrm{D}$

Here I is the set of individuals and D is the set of degrees appropriate for the measurement. Actually, I will argue below that there are other sorts of measure functions, but (29) defines the appropropriate type for a measure function usable for extent readings. The examples in (28) suggest that in such a function X and S may not be the same. More generally, they may not coincide or be parallel.

Thus, whether an extent reading is possible for *lengthen* depends not just on whether a spatial axis is available in context, but on the particular *orientation* of that axis.

Now consider how axis orientation constraints might apply to a verb like *cover*.

(30) a. The leaves gradually covered the driveway.
b. The aneurysm grew as it approached the valve and gradually covered it.

Although example (30a) has a perfectly acceptable event reading, it has no extent reading, as noted in (20); on the other hand, (30b) does seem to have an extent reading. This is an extent reading with *cover* for which the adverb *gradual* is felicitous. Over some past onterval I, as the aneurysm grows closer to the valve, the aneurysm expands, and that expansion is gradual. An aneurysm is a bubble on a large blood vessel; the axis along which change happens is the axis of the blood vessel. Thus, the distinctive feature of this example is that the change axis clearly lies outside the plane of the valve, because it passes through the surface in which the valve is set. Now, in default uses of *cover*, the only relevant spatial axis is that exploited by path phrases, and that axis lies in the plane of the covered object (what I will call the *ground*). This is illustrated in (31):

(31) Snow gradually covered the valley from the hut to the river. (axis defined by points along valley surface, event reading only)

In the case of (30), the axis clearly lies outside the plane and is roughly perpendicular to it, making an extent reading possible. Interestingly, when we add path phrases to (30), they must still describe features that lie in the plane of the valve:

(32) The aneurysm grew as it approached the valve and gradually covered it from end to end.

The only interpretation of the path phrase is *from (one) end of the valve to the other*; it cannot be interpreted as meaning *from (one) end of the aneurysm to the other*. Thus, it appears that for this example, rather exceptionally, there must be two distinct spatial axes, the axis of change and the path axis.[5]

In sum, orientation of the axis is a major factor: When the axis of change is parallel to or in the plane of covering (and as a matter of default, it is), examples with *gradually* are incompatible with extent readings. But when the context forces the axis

[5]The constraints being observed here on path phrases for *cover* are not unique to such exotic examples and seem to follow form the figure-ground relations incorporated into the verb. Thus, for example, the path phrases can never locate something in terms of reference points on the figure. They must always be reference points on the ground (thanks to Chris Barker for this example):

(i) The flag covered the pillow from the 5th stripe to the 12th stripe. [# if the stripes are on the flag.]

This, then, is another reason to suppose that the path phrases with *cover* are lexically selected.

to be normal to the plane of covering, as in (b), graduality is compatible with the extent reading.

Axis orientation has another kind of effect: It affects the interpretation of path-phrases. Consider event readings of the sentences in (33):

(33) a. The ball rolled from the front of the table to the back.
  b. The crack widened from the north tower to the gate.
  c. The aperture widened from the edge of the door frame to six inches beyond it.

It has been observed by a number of authors (especially Dowty 1991 and Krifka 1998) that paths of motion verbs are incremental themes. Since we will be discussing other possibilities, I will call such paths **incremental paths**. What this means for (33a) is that the start of the path (the front of the table) coincides with the ball at beginning of the rolling event and that the end of the path (the back) coincides with the the ball at the end of the event. The path grows homomorphically with event. This is not true for the event reading of (b). The event of crack widening may proceed in any order as long as at the end of the event the widened-portion of the crack extends from the north tower to the gate. Thus, on the event reading of (b), in contrast with the extent reading, the ordering implied by *from* and *to* has no truth-conditional effect. Conclusion: The path is not an incremental theme. Note that there is in a literal sense motion in both (a) and (b), but in (b) the widening motion is orthogonal to the axis of the path phrase. In other words the direction of widening is roughly at right angles to a line connecting the tower and the gate. In (b) the direction of motion roughly follows the path axis.

In (c), however, the path once again is an incremental theme. This is precisely the example we saw in (28d), which lacked an extent reading because of axis orientation. Note that in this case the direction of the axis along which the width is increasing (the path axis) coincides with the direction of measurement. That is, the axis of measurement *is* the axis of change. This is in contrast to examples like (28a); the consequence relevant here is that the widening motion travels along the path axis. This is the definition of motion I will use throughout this paper: Motion is movement along the path axis.[6] Sentence (28d) exhibits this kind of movement, whereas the widening motion in (28a) does not. I will propose an account of path phrases in Section 3 in which this difference in entailment correlates with the difference between incremental and nonincremental paths. This difference is axial in nature.

The plan for the rest of this paper is as follows.

(34) a. A definition of the notion of change along a spatial dimension, along with a detailed demonstration of how aspectual aspectual underspecification works (for *widen*) will be given in Section 2.1;
  b. Some differences between the analysis here and the GHKL analsys will be outlined and motivated in Section 2.2;
  c. The extension of the account to cases like *cover* and *extend* and the account of axiality constraints will be given in Section 2.3.

[6]This matches the definition of motion in Talmy (1985).

d. The account of path phrases will be given in Section 3;
e. A remaining difficulty is the case of *cross* (and the other path-shape verbs). Nothing said thus far has offered any reason for why *cross* passes our test for being spatially dynamic, as in (24), and *cover* and *extend* do not, as in (22) and (23). The difference between *cross* on the one hand, and *cover* and *extend* on there, will be discussed in Section 4.

In general the motivation for the study of idiosyncratic phenomena in linguistics is that they teach us about the underlying principles. In the best of cases idiosyncratic phenomena are completely predictable from the interactions of general principles. In more familiar circumstances, some stipulation is required, along with some adjustment of our understanding of how the general principles work. This seems be the case of event-extent verbs. In the first place, this extension of the machinery of temporal aspect into the spatial domain teaches us something about basic aspectual notions like state and dynamic gradable property, how they map into syntactic categories like verb and adjective, and how they interact with well-attested aspect-changing operators like BECOME/INCREASE. In the second, in order for the basic generalizations to be captured, they require the stipulation that certain kinds of lexical classes exist, and key properties of those classes may well be specific to English. For this purpose, some notion such as the notion of a lexical **frame** (Fillmore and Baker 2000) or a verb class (Levin 1993), is needed. Once the class properties are stipulated, as for the path-shape verbs, the rest follows from general principles of aspect.

2 Basic analysis

In this section I lay out the basics of an analysis that uses spatial axes as axes of change, yielding spatially dynamic readings, and formulate the key axial cosntraint on spatially dynamic readings, **the independence principle**. I will rely in large part on the treatment of Gawron (2005), though there are significant changes to be motivated. I illustrate with the analysis of *widen*.

2.1 The basic analysis: Spatial axes

I will begin with the first assumption required in order to account for extent readings: There is such a thing as change with respect to space.

Now what is required to make sense of such an idea? What is required is the concept of a *spatial axis*, an ordered set of co-linear points that can serve as an *axis of change*. I further argue further that such axes that are independently motivated for the language of space, and they interact with extent readings in just the way expected if they are axes of change.

My starting assumption is that descriptions of change require two ordered sets. Consider (35):

(35) The boiling point of water drops 3 degrees Fahrenheit between sea level and 4000 feet.

This example describes a change, a functional dependence between altitude and boiling point that is independent of time. As the altitude increases the boiling point falls. But in order for that description to make sense, altitude has to be something that can increase and boiling points something that can fall. Functional change is the existence of some correlation between two ordered domains, and change with respect to time is a special case of that.

Treating change with respect to space as another case of functional change thus raises the following issue:

In what sense can space be thought of as an ordered domain?

An obvious answer is to organize space by means of axes, as we do with Cartesian coordinate systems. This is not the only possibility but it has the attraction of simplicity. The first step in accounting for change with respect to space, then, would be the addition to the semantics of an *axis of change*, informally defined and exemplified in (36):

(36) a. **An axis** is a set of elements with a well-ordering.
b. The Fahrenheit scale is an axis, and in (35) it is used as an axis of change to measure change in boiling points.
c. A line parallel to the face of the wall is the axis of change in (1b).

Adding contextually supplied spatial axes to the semantics would be a lot to swallow if they existed merely to handle extent readings. However, spatial axes seem to be quite well motivated by other phenomena; moreover, the same spatial axes we need elsewhere seem to be exploitable for extent readings. Consider (37a) and (37b). Fong (1997) calls these *diphasic locatives*.

(37) a. the road (in)to Ukiah
b. the road out of Ukiah
c. The road into Ukiah widens 5 feet at the wall.
d. The road out of Ukiah narrows 5 feet at the mall.

Sentence (37a) describes a particular road as a path into Ukiah; in (b), the same road may be a path out of Ukiah. Two perspectives are taken on the same road, differing in some way that imposes directionality on how the road is viewed. Fong accounts for such directionality by use of an oriented spatial axis. Space precludes a detailed consideration of her account; two points are important. The first point is that an axis is required. As I did for the axes assumed for extent readings in Section 1, I will call this the *context axis*. The second point is that the directionality of Fong's axis interacts directly with extent readings. Sentence (37c) asserts that the road's width at the mall increases in the direction toward Ukiah, that is, in the same direction as Fong's axis points; (37d) asserts that it decreases in the direction away from Ukiah, again the direction of the spatial axis. We can account for this if we simply assume that the context axes in (37a) and (37b) are identified with the axes of change.

A more familiar example arises in the case of projective prepositions such as *behind, in front of, in back of, above, below, beside,* and *ahead of*:

(38) a. The futon is behind/beside the chair.

b. The futon is behind the boulder.
c. The dress lengthens in back.

In (38a) the futon's location can be described as *behind* the chair, which we will call *the ground*, because a chair is the kind of object that has a canonical back and front, determining the direction of an axis from the front through the back. I will call this kind of context axis, in which the ground has a canonical orientation that determines the direction of the axis, *intrinsic*, following Fillmore (1971), Tversky (1996). In (38b), the boulder has no such canonical sides and some contextually determined point (let us call it a point of view) must determine the direction in which "behind" lies. What unifies these examples with those in (37) is that directionality is involved, and this directionality seems to be describable via an axis that goes through the ground, Ukiah in (37), the chair and boulder in (38). (38c), reproduced from the introduction, shows that the directionality of projective PPs, like that of diphasic locatives, interacts with extent readings. The direction in which the dress's length must increase in (38c) is from the dress's front toward its back, that is, the same direction as its intrinsic front-to-back axis. In brief, the context axis is identified with the axis of change.

I now turn to illustrating how these observations leads to an analysis of event-extent ambiguities, focusing on (1b) as the first example. What is going on in the event reading of (1b)? Widths may vary in time; and events of widening in time are events in which the width of the theme at the beginning of the event differs from the width at the end. What is going on in the extent reading of (1b)?

The key idea of GHKL analysis is that (1b) exploits a contextually provided spatial axis to measure out change. Thus, we find if we measure the width of the crack moving up along that axis in the selected interval that it is increasing. What does it mean to measure width "up along" a spatial axis? It means the points on the axis are ordered and as we moved in the "upward" direction on the axis, the width increases. What does it mean to measure the width of an object x "at a point" s on an axis? It means we imagine a plane P perpendicular to the axis and measure the width of the intersection of P with x. This means that we can have a single measure function

(39) $\textbf{wide}^{-}_{\mathrm{S}}(x,\ s,\ t) = d$,

where d is the width of x as measured at position s on a spatial axis, S and time t.

Note that the introduction of a contextually provided spatial axis S is independently motivated, this time very specifically by the semantics of width:

(40) a. The cabinet is 6 feet wide.
b. The mountain is 6 miles wide

Here the cabinet has canonical orientation axes, with one usually favored for widths, but the mountain does not. It must be context, "point of view", that orients the axis. The axis along which widths are measured, called the **measurement axis** in the introduction, must be perpendicular to the front-to-back axis in (1b), along which widths may change. The front-to-back axis is what I have been calling the **context axis**. Canonically, the context axis connects the *ego* to the figure, this analysis makes no explicit reference to *ego* (or viewer).

Motivated by examples like (40), I assume that every token of *wide* exploits a context axis S. Sentence (40b) may be then used to make the following sort of claim: the mountain has a certain width over some interval of context axis S at a certain time t. On the default interpretation of (40b), the relevant interval of S includes the entire mountain. That is, (40b) is generally used with fairly inexact standards of precision to ascribe an overall width to the mountain.

More restrictive types of claims can be made with sentence including a temporal or locative phrase:

(41) a. The river was 15 feet wide at 3'o'clock.
b. The mountain is 6 miles wide where the highway crosses over it.

Intuitively, what is going on is that these modifiers constrain the temporal and spatial extent of the width state-of-affairs, and thus the interval over which the width is constant. Figure 2 gives a picture of such a width measurement for the mountain in (41b). Part (a) represents the mountain; (b) orients it with a context axis S and shows a sequence of slices of the mountain defined by successive points along that axis; (c) shows the width measurement for one slice, where the road crosses. The axis of measurement is μ_0.[7] The kinds of temporal and spatial modifiers shown in (41) can very naturally be handled as properties of eventualities.

Thus, I will assume the semantics of a simple adjectival use of *wide* is:

(42) a. The crack is a half inch wide.
b. $\exists\sigma[\mathbf{wide}_{\mathrm{S,T}}(\sigma) = [.5\ \mathrm{in}] \wedge \textit{figure}(\sigma) = c]$

Neither the adjective meaning for *wide* nor the verb meaning for *widen* will directly make use of the measure function wide$^-$ introduced in (39), for reasons outlined in Section 2.2. Rather the denotation of the adjective is assumed to be a function from eventualities to degrees like $\mathbf{wide}_{\mathrm{S,T}}$ in (42b). Very briefly, the eventuality function and the measure function are related as follows:

(43) $\mathbf{wide}_{\mathrm{S,T}}(\sigma) = d$ iff σ is classifiable as a width eventuality and for all s in S_σ all T in T_σ

$$\mathrm{wide}^-(\mathrm{figure}(\sigma),\ s,\ t) = d$$

The subscript T on $\mathbf{wide}_{\mathrm{S,T}}$ refers to the time axis and the subscript S to the spatial context axis; S_σ refers to the axis restricted to the portion "in" the spatial trace of σ, and T_σ refers to the T axis restricted to the portion "in" the temporal trace of σ. The definition requires σ to be a width eventuality and the width of the figure of σ to be d for all spatial and temporal indices "in" σ. Thus, σ is temporally brief enough and spatially small enough so that the width of its figure is constant throughout. The width is **homogeneous** throughout. I will call any eventuality function which imposes such brevity and smallness conditions on its eventualities a **state function**, and I will have more to say how adjectives are assigned such denotations in Section 2.2.

[7]Note that there are an infinite number of lines perpendicular to S at the measurement point. So the axis of measurement is further constrained by some contextual or canonical factor; most usually it must be horizontal.

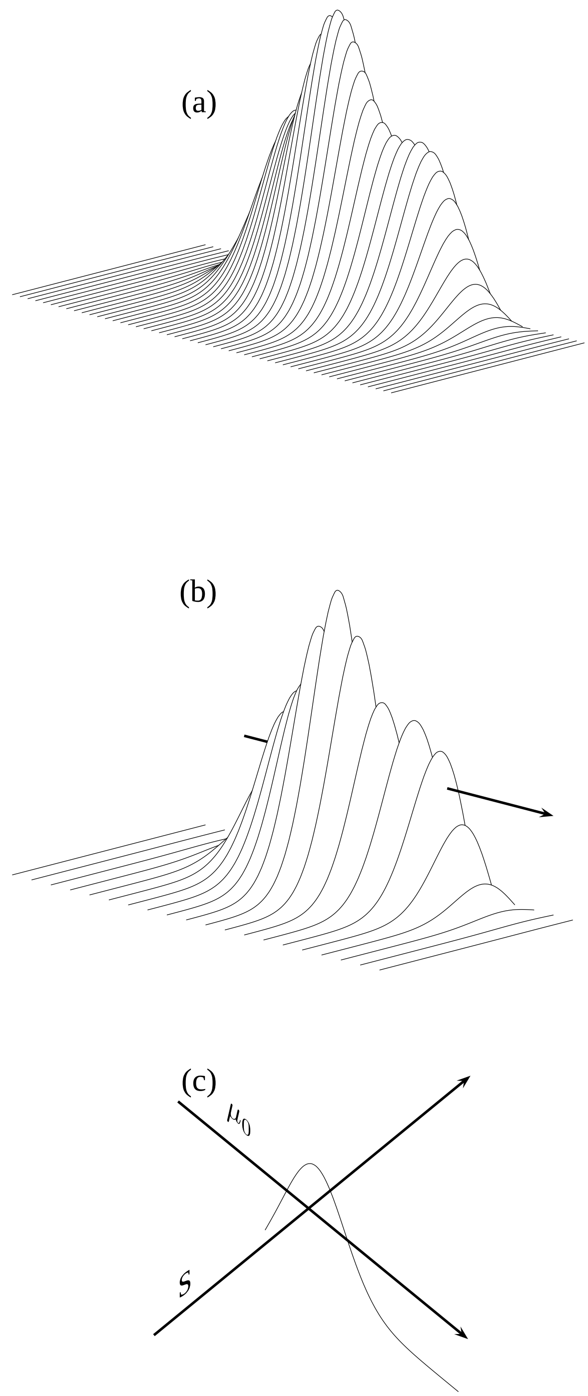


Figure 2: Widths and slices: μ_0 is the axis of measurement for a width measurement at a point on S.

In the rest of this section we follow GHKL and extend the basic scalar adjective analysis to degree achievement verbs, using the example in (44):

(44) The crack widened half an inch.

To begin with, here is a somewhat modified version of the axiom HKL use to define INCREASE:[8]

(45) $$\forall d,\, e \left[\begin{array}{c} \text{INCREASE}(\text{wide}_{\text{S,T}})(e) = d \\ \longleftrightarrow \\ \exists \sigma_1, \sigma_2\, [\text{START}(e,\, \text{wide}_{\text{S,T}},\, \sigma_1)\ \wedge \text{END}(e,\, \text{wide}^{\text{S,T}},\, \sigma_2) \wedge \\ \quad \textbf{wide}_{\text{S,T}}(\sigma_1) = \textbf{wide}_{\text{S,T}}(\sigma_2) + d\,] \end{array} \right]$$

A widening event is one that relates to two width states, the width state at the event's beginning and the width state at the end, with the difference in width measures, d, equaling the width increase of e:

$$\text{increase}(\textbf{wide}_{\text{S,T}})(e) = d$$

The predicates START and END will be discussed and revised in Section 2.2. For now, it suffices to note that $\text{START}(e,\, \textbf{wide}_{\text{S,T}},\, \sigma)$ is true only if:

(46)
a. $\sigma \sqsubseteq e$;
b. $\text{START}(\sigma) = \text{START}(e)$
c. $\text{figure}(\sigma) = \text{figure}(e)$
d. $\text{width}(\sigma)$ (where width is a predicate dependent on $\textbf{wide}_{\text{S,T}}$ classifying width eventualities).

The consequences for END are symmetric. The principal effect of the START and END requirements in (45), then, is to guarantee that σ_1 and σ_2 are starting and ending width states of e. Since the states used by INCREASE will be required to be homogeneous with respect to the underlying measure function, it is not necessary to assume that there are unique starting and ending states; hence START and END are not functions.

The revision required to admit extent readings is simply to make INCREASE, START, and END all sensitive to what axis change is being measured on. Using α for the axis of change, whether temporal or spatial, we would revise (45) as follows:

(47) $$\forall d,\, e \left[\begin{array}{c} \text{INCREASE}_{\alpha}\,(\textbf{wide}_{\text{S,T}})(e) = d \\ \longleftrightarrow \\ \exists \sigma_1, \sigma_2\, [\text{START}_{\alpha}\,(e,\, \textbf{wide}_{\text{S,T}},\, \sigma_1)\ \wedge \text{END}_{\alpha}\,(e,\, \textbf{wide}_{\text{S,T}},\, \sigma_2) \wedge \\ \quad \textbf{wide}_{\text{S,T}}(\sigma_1) = \textbf{wide}_{\text{S,T}}(\sigma_2) + d\,] \end{array} \right]$$

α , the axis the INCREASE operator exploits, is the axis of change. When α is spatial it must be a contextually supplied axis, and the most salient one is the adjectival context axis S, each index of which determines a cross-section of the theme with a (potentially different) width. When α is temporal, we simply have the case of (47) again.

Generalizing the START and END relations to spatial as well temporal axes requires defining the start/end of an event with respect to either kind of axis. For example, the definition of the **start** of an event with respect to an axis α is:

[8]The modifications will be defended in Section 2.2. Basically, they have to do with assigning adjective meanings an eventuality argument, which HKL do not do.

(48) $\text{START}_\alpha(e) \;=\; \underset{p \in \alpha_e}{\text{Min}}\; p$

where α_e is simply axis α restricted to e. Thus, the start and end of e along axis α are the respective minima and maxima of the projection of e's spatiotemporal trace, $\mathcal{T}(e)$, onto α . An event will thus have different starts and ends, depending on what axis is used, and accordingly defines intervals on all relevant axes.

We have now said enough to address the case of (44). In terms of the lexical entry for *widen*, I assume the following:

(49) $[\![\text{widen}]\!] = \text{INCREASE}_\alpha(\textbf{wide}_{\text{S,T}})$ where $\alpha \in \{\text{S, T}\}$

Thus, the variable α present in the lexical entry of *widen* is may be instantiated in one of two ways:

(50) a. $\exists e\ [\text{INCREASE}_\text{S}(\textbf{wide}_{\text{S,T}})(e) = [\text{in } 5] \wedge \text{figure}(e) = c]$
b. $\exists e\ [\text{INCREASE}_\text{T}(\textbf{wide}_{\text{S,T}})(e) = [\text{in } 5] \wedge \text{figure}(e) = c]$

The extent reading of (44) is represented in (50a) as the choice of S, the context axis for *wide*, as the axis of change subscripting INCREASE; the event reading in (50b) as the choice of T, time, as the axis of change. Accordingly I will write:

$$\text{widen}_\alpha = \text{INCREASE}_\alpha(\textbf{wide}_{\text{S,T}})$$

According to our revised version of (47), both readings are true if and only if the difference in the value of the width function between the start and end of e as measured on the axis of change α is .5 inch.

As noted in the introduction, this analysis of the ambiguity of (44) makes no use of an aspect-changing operator, such as the inchoative operator used in the analysis of extent predicates in Jackendoff (1990), to distinguish the readings. Essentially the same meaning is claimed to yield both readings, the difference residing in which axis is used to instantiate α .

We have now mapped out a basic framework in which spatial axes can be exploited as axes of change by dynamic predicates. The predicate widen_α is, as the morphology of the verb indicates, inherently dynamic, but from the point of view of temporal aspect it is aspectually underspecified. That is, its definition is consistent with eventualities that are temporally states (in which the required change happens along the S-axis), or with eventualities that are temporally events (in which the required change happens along the T axis).

A key feature of the account of *wide* and *widen* is that both denote functions from eventualities to degrees, which I have been calling **eventuality functions**. The denotation of *wide* measures the degree returned by some measure function and obtaining throughout the eventuality, while the denotation of widen_α is an eventuality function that returns the degree of change in the eventuality. Hence I call the denotation of *wide* a state function and the denotation of *widen* an event function.[9] Having both state and event functions be of a single type is what leaves the door open for an underspecification

[9] I will give a precise definition of state functions in Section2.3.

analysis of event and extent readings. Stative and dynamic predicates are not fundamentally different kinds of things, and shifts between stative and dynamic readings depend on something other than a shift in type.[10]

With some of the details of the account of state functions filled in I now return to the question of axial restrictions on predicates. We begin with the facts in (28), which established axial restrictions on extent readings of *widen* and *lengthen*.

Our basic hypothesis about dynamic extent readings is that they arise when a context axis is exploited as an axis of change.

Let's begin by making clear that the phenomenon of interest really arises independently of dynamic readings, with adjectives:

(51) a. The river is 20 feet wide at the the ford.
b. The river is 20 feet wide from Miller's landing to the bridge.

These examples are descriptions of states, but they presuppose a world in which spatial properties can meaningfully vary, and the context axis is constructed so that it contains points p such that width measurements can meaningfully take values at p. Consider the schematic representation of a river in Figure 3. The river is an irregularly shaped object with a salient length axis represented by the dotted line. It changes widths continuously along that axis, so that it makes sense to speak of width measurements taken at various points along the axis, indicated by the solid lines across the river. The indices of such measurements can be described using locative *at*-phrases as in (51a), or their persistence and stability over an interval on the axis can be described using path phrases as in (51b). I will refer to a context axis which can be used to locate such measurements for state descriptions as an **axis of reference** and I will use the two kinds of modifiers in (51) as a diagnostic that a stative predicate can use a particular axis as an axis of reference.

Not every context axis can be used as an axis of reference. Thus consider the case of the door aperture pictured in the after-part of Figure 1. If the aperture picture is 10 inches wide total, with 4 inches inside the door frame, and 6 beyond it, we can not say:

(52) The aperture was 4 inches wide at the door frame.

to assert that the portion of the aperture extending from the center to the door frame was 4 inches wide. Similarly, if we refer to the cross-piece separating a knife hilt from the knife blade as a **cross-guard**, we cannot say of a knife that has a 6 inch blade and a 4 inch hilt:

(53) The knife was 4 inches long at the cross-guard.

Both these infelicities can be described as failed attempts to use a context axis as an axis of reference. In both cases the context-axis in question coincides with the axis of measurement. As we saw in (28) the same restriction applies to dynamic extent readings. In stating the restriction I will use the following definition:

[10]Also measure functions may be related to dynamic eventuality functions without the need of intervening state.

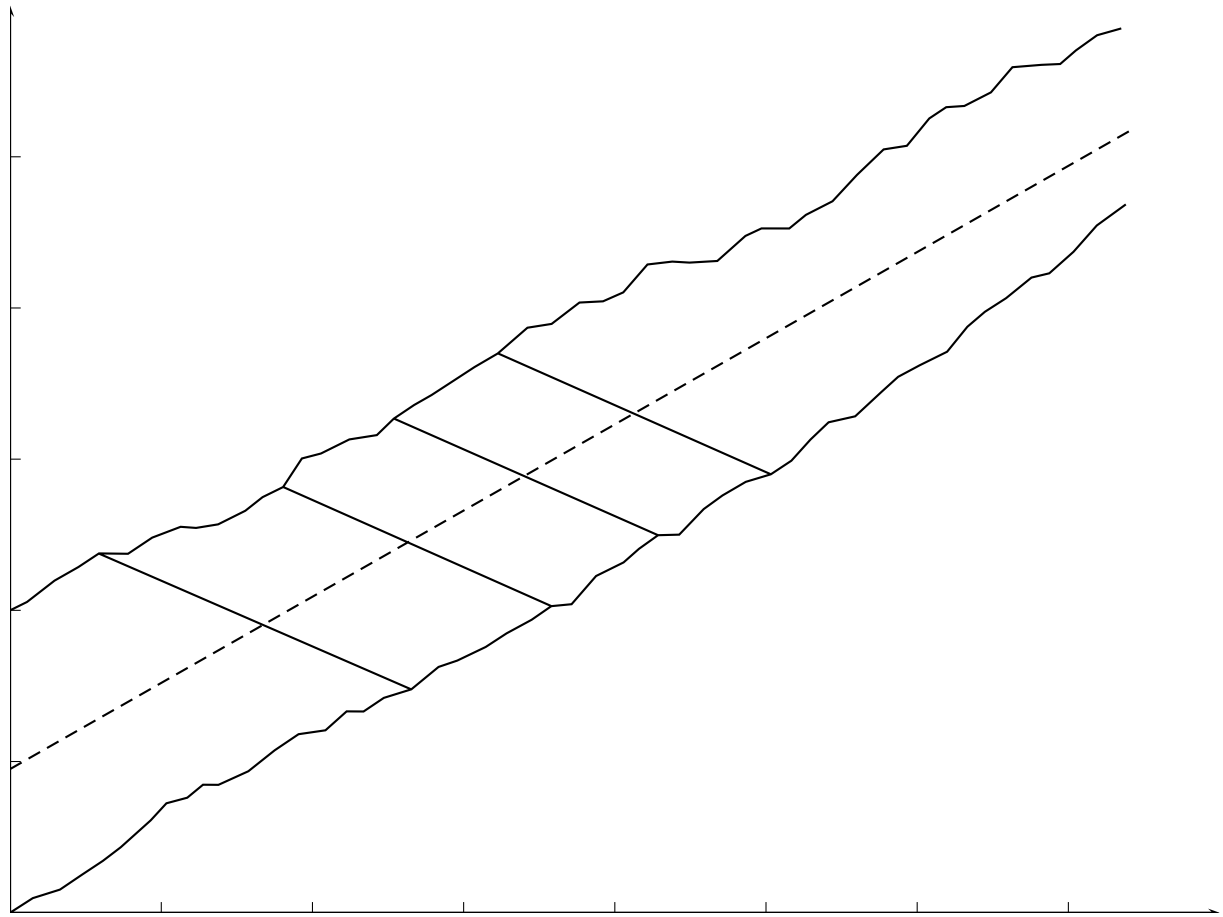


Figure 3: A context axis that is also an axis of reference

Reference Axis

A **reference axis** is a context axis used for locating a measurement. It can be either time (T) or a spatial context axis (S)

The key constraint on orientation can be stated as follows:

Independence Principle (IP)[11]

For distance measurements, a reference axis must be independent of the axis of measurement; that is, it cannot be parallel to or coincide with the axis of measurement.

The descriptive generalization that dynamic readings rely on an axis of reference can be stated as follows:

The α Generalization

The α axis used by INCREASE_{α} must be a reference axis.

[11]The restriction the IP imposes on the relation of the mneasure axis and erefernce axis is very close to the condition two vectors must meet in ordr to be the bases of a 2D vector space, They do not need to be geometrically orthogonal. But they may not point in the same direction.

The need to distinguish reference axes from other context axes arises because there are legitimate context axes that are not reference axes, as in (28d). Since (28d) has only an event reading, the reference axis must be Time. Nevertheless, a spatial context axis is still exploited by the path phrases. I will call a context axis that is not a reference axis a **path axis** (because the salient function in this system of such axes is for orienting paths).

How is the α Generalization and the Independence Principle to be captured? I turn first to the Independence Principle. I will argue that given two natural assumptions about measure functions, the IP falls out:

(54) a. When measuring along the measurement axis, the only possible magnitude for a distance measurement *at a point* is 0.
b. Distance scales like length and width do not have 0s.

Consider the two width measurements in (28). In (a) the cable's width at any point along its length axis has positive values; but what is the width of the aperture in (d) at a point 3 inches from the center, measuring along a radius? Assumption (54a) says the only magnitude a width can have measuring at a point on the width axis is 0, and assumption (54b) says there are no 0-magnitude widths on the width scale. Therefore, the width measurement function will undefined at points on such axes.

Given these assumptions, we will see in Section 2.2 that the α generalization follows from a very natural restriction on $\text{INCREASE}_{\alpha}(f)$, that it apply only to eventuality functions f that are homogeneous along α. Basically, for any σ and d such that

$$f_{\alpha}(\sigma) = d$$

the measure function underlying f must return d for every point in α_{σ}. In order to do this, of course, f must be defined at every point on α_{σ}, and that is only possible when α is a reference axis. Thus the α generalization is subsumed by the following Homogeneity Principle (The Homogeneity Principle will be stated more precisely in Section 2.3.):

The Homogeneity Principle:[12]

The INCREASE_{α} can only apply to eventuality functions that are homogeneous along α.

These considerations strongly suggest that the lack of evidence for spatial dynamic readings for *extend* can be acounted for by its axial properties. It is apparent that the orientation of path phrases is in the direction of movement and measurent with event and extent readings of *extend*:

[12]Gawron (2005) tries to derive the effects of axial constraints with a simpler cumulativity cponstraint on the application of INCREASE_{α}. The problem with this approach is that it cannot distinguish canonical uses of *cover* from that use non canocial axes and have spatial dynamic propertis such as graduality. Example (30b) is of this variety. Essentially, the approach of Gawron (2005) rules out (30b). The approach pursued here adopts the IP as a cosntraint on what it means for a function to take a value **at** a point on a spatial axis, then tries to derive all the rest from that. For example, the Homogeneity Principle does the necesssary work because the IP rules out having certain functions be homogeneous along certain axes.

(55) a. His arm extended into the air.
b. The beam extended 15 feet past the column.

Thus, the verb has a strong preference for a context axis that coincides with the measurement axis; therefore no homogeneous eventuality function can be defined and no dynamic predicate can be derived using INCREASE_S; this leaves only INCREASE_T to derive a dynamic predicate. Thus there is no reason to expect *gradually* to combine with extent readings for *extend*, because there is no derived spatially dynamic version of *extend*. Similarly there is no reason for Vendlerian tests for a dynamic predicates to succeed along the spatial axis.[13]

It is possible to account for the restrictions on *cover* along the same lines, although there are differences in detail. To begin with, it is not clear what the notion axis of measurement means when we are dealing with a 2-dimensional (areal) measurement. But it seems reasonable to suppose the following:

(56) a. When the context axis S lies parallel to or in the plain of covered surface, the only possible value the cover function could take *at a point* is 0.
b. The cover scale has no 0, so it is undefined for points on path-axes.

Given the homogeneity principle, then, the non existence of a derived spatially dynamic predicate follows.[14]

Summarizing this section, we have laid out what it means for a degreeable predicate to change along a spatial axes. We have sketched how spatially indexed states work, and how dynamic predicates might be derived from them, following the lines of the original HKL analysis. This illustrates the basic case of what was called an underspecification analysis in the introduction. There is one derived predicate $\text{INCREASE}_\alpha\,(\mathbf{wide}_{\alpha\,,\beta})$, which can describe change along either temporal or spatial axes. We have also discussed some constraints on spatial axes that affect which spatially dynamic readings are possible.

2.2 States

The analysis presented in the previous section makes use of functions from eventualities to degrees. Informally, I have distinguished the functions that enter into adjective

[13]This does not rule out the possibility that graduality might arise because *extend* is inherently spatially dynamic (without the intervention of INCREASE_S). We will rule out this possibility in Section 4.

[14]It might be thought that the existence of extent-reading examples such as

(i) A canvas covered the road at the cross walk.

provide evidence that *cross* can use a reference axis in the plane of the road, since the locative seems to be identifying a point *on* the road, whose length axis ought to be ineligible as a reference axis. However, despite the use of an *at*- phrase, the fact that a measurable area (the area of the canvas) is involved shows that this path-phrase still corresponds to an interval of the road, and is no different in kind than:

(ii) The canvas covered the road from one crosswalk to the other.

We are not here considering the case of examples like (30b), where *cover* in the occlusion sense uses a non-default axis which is a reference axis. These will be addressed in Section 2.3.

denotations, calling them **state functions**, and the eventualities in their domain, notating them σ, and calling them **states**. Since the precursors of this analysis — Hay et al. (1999) and Kennedy's analysis of adjective semantics on which that is based (Kennedy 1999a, Kennedy 1999b) — do not assume states; and since it has been proposed that, within an eventuality-based semantics, states should be represented as propositions that make no reference to eventualities (Kratzer 2000), this feature of the analysis needs to be defended.

The first point to be made is that the original Hay et al. (1999) analysis has a problem which the use of state-eventualities solves. Consider the original version of the INCREASE axiom:

(57) $\text{INCREASE}(f)(x)(e) = d$ iff $f(x, \text{START}(e)) + d = f(x, \text{END}(e))$

Here f is an adjective denotation like *wide*, and $\text{INCREASE}(f)$ is being defined in order to serve as the denotation of the verb *widen*. Thus, part of the job of the definition is to define what counts as a widening event. But look what the definition says when run in the leftward direction: It says that any event that starts and ends at the same time as some course of widening counts as a widening event. So, according to (57), if a fissure in a glacier in New Zealand widens 3 inches (e_1), it can also be truthfully said of an event of sheep-shearing in Scotland (e_2), which starts and ends at the same time:

$$\text{INCREASE}(\text{wide})(\text{fissure})(e_2) = [\text{inch } 3]$$

While this may not seem an unwelcome result to those eager to have fewer events, it will very quickly get us into truth-conditional trouble, given the standard Davidsonian account of other adverbial modifiers. For example, on this account it follows from the facts of the glacier-fissure-widening, the simultaneous sheep-shearing, and the fact that the sheep-shearing is in Scotland, that a glacier-fissure-widening event has happened in Scotland, which as it happens has no glaciers.

Thus this definition does not succeed in integrating a non-eventuality-based account of adjective denotations with an eventuality-based account of the verb meanings derived from them.

The fix proposed here, and presupposed in (47), is simply to change the denotation of a degreeable adjective from what Hay et al. (1999) assume it is, a function from individuals and times to degrees (what I have been calling a **measure function**) to a function from eventualities to degrees (what I have been calling an **eventuality function**).

Measure function	$\text{wide}(x, t) = d$
Eventuality function	$\mathbf{wide}_{\text{S,T}}(\sigma) = d$

In Section 1, I called the particular kind of eventuality function used for adjective denotations a **state function**. State functions are not intended as a replacement for measure functions; both state functions and measure functions have formal properties relevant to the main concerns of this paper and it is important to state the relationship between them clearly. I now turn to this task.

A state function is really a hybrid of an event classifying predicate and a measure function, combining both kinds of ideas. The motivation is that both kinds of work need to be done. But it is important to note that event classification is really the prior idea. The idea of a class of events as used in event semantics is really a cluster of ideas. Classified event types come with associated regularities, usually articulated as functions on the eventuality type called roles. An eventuality function is really just a role filled by a degree. Thus, the idea of an eventuality function is not controversial if one embraces a neo-Davidsonian event semantics. Whether one adopts an HKL type analysis of events or not, classifying an event as a motion event comes with the idea that there is a measure function returning the distance covered. Thee easiest implementation of this idea in Neo-Davidsonian event semantics is a role returning the distance. The controversial part of the proposal is that we extend eventualities and event functions to adjectives. At the same time, we want to keep measure functions in the picture.

Let us assume that measure functions are basic, but that predicates classifying certain eventualities as measuring eventualities of certain kinds are also basic. We then define state functions in terms of **both** via a family of *state-function operators*. The simplest operator is the one for one-dimensional adjectives like *heavy*, which are evaluated only along the time dimension. We define the state-function for *heavy* by applying the operator $\boxdot^{\mathrm{T}}$ to the classificatory predicate *height*, true of all and only those eventualities that are height-eventualities, and the measure function *height*$^{-}$. In other words, The form of the definition is:

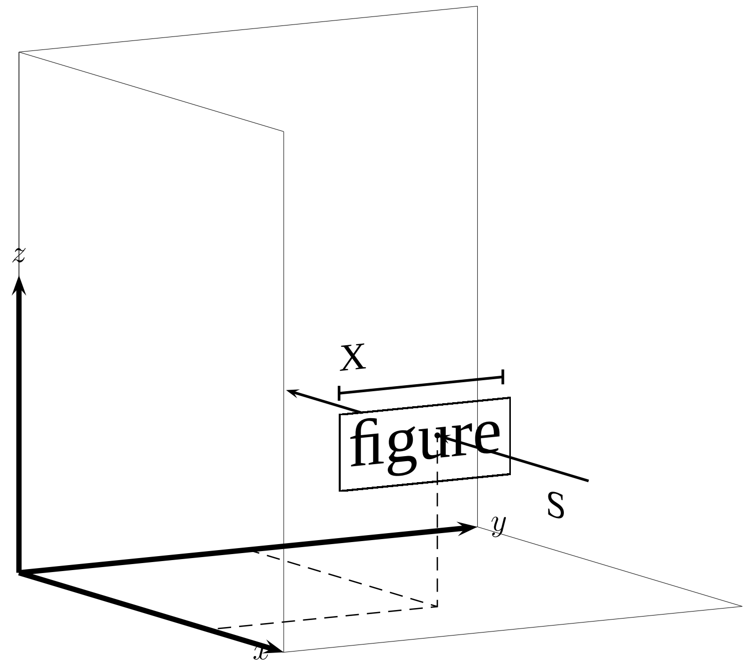
(58) $\mathrm{heavy_T} = \boxdot^{\mathrm{T}}(\mathrm{height_T},\ \mathrm{height_T^-})$

T is the time axis, as before. The measure function weight^{-} returns the weight of the figure at a time t.

The adjectives of interest in this paper are those that introduce a spatial axis, like *wide*. For such adjectives, we need a distinct operator $\boxdot^{\mathrm{S,\,T}}{}_{x}$that makes reference to the spatial axis. the form of the definitions with this operator will be:

(59) $\mathbf{wide}_{\mathrm{S,T}} = \boxdot^{\mathrm{S,\,T}}{}_{x}(\mathrm{width_{X,S}},\ \mathrm{distance^-_{X,S}})$

Again *width* is a predicate true of width eventualities. S and T are reference and time axes, as before. X is the axis of measurement. The measure function distance^{-} returns the distance along X occupied by the slice of the figure at s at a time t, as shown in (60):



(60)

The classificatory function *width* will be responsible for guaranteeing that the measurement axis X really is a width measurement axis. The contentful claim made by the kind of definition of adjective denotations exemplified in (59) is that an adjective denotation has two independent components, a classifying predicate and a measure function. This idea would gain significantly in credibility if we could find instances where the two varied independently. It does at least seem to be plausible to posit classes of adjectives that share measure functions. For example, the measure function distance^{-} is common to various distance adjectives such as *high*, *long*, *tall*, *short*, *deep*, *narrow*, and *wide*; and it is primarily the relation of figure to axis that varies.

In addition, adjectives have selectional requirements just as verbs do, and it is reasonable to suppose that the predicate classifying eventualities is responsible for imposing those requirements for both verbs and adjectives.[15] Thus, just as the eventuality predicate for *frighten* selects whether *sincerity* is an appropriate argument for the experiencer argument, the classificatory predicate for *tall* and *high* will determine whether a mountain is an appropriate argument for the figure role.

When we turn from adjectives to verbs, the case for separating classificatory predicates from measure functions becomes even stronger. Hovav and Levin (2002) suggest that a single core verb meaning may be associated with distinct scales, adducing examples from the domain of **surface contact verbs** such as *scrub*. Consider scrubbing a tub. There is one scale provided by the tub's surface area and another by a scale of cleanliness This, in part, is why *scrub* has such complex telicity conditions:

[15]Possibly, as has often been suggested, selectional restrictions are best described by factoring their effects into *roles*. But this fine point does not affect the general point being made here. In that case classifying predicates are responsible for role signatures and roles are in turn responsible for selection restrictions.

(61) a. Lee scrubbed the entire tub for hours. (atelic; cleanliness)
b. Lee scrubbed the entire tub in minutes. (telic; may be surface area)

The verb *scrub*, then, would be an example of a verb with a single classifying predicate, identifying events in which a certain kind of surface contact is going on, and distinct measure functions.[16]

Similarly there are degree-achievement-like verbs that plausibly share measure functions but differ only in selection restrictions or precise event class properties. Examples would be: *expand* vs. *grow* (a single size function), *rise* vs. *ascend* (a single altitude function), *climb* vs. *ascend* (a single proportion-of-ground-climbed function), *polish* vs. *shine* vs. *wax* (a single shinyness function). The argument back to adjectives, then, is: With eventuality classification required for both verbs and adjectives, we must formulate the classifications in a way that allows the measure function to be separated out for both.

There seem to be two natural ways to define $\boxdot^{\mathrm{S,\,T}}{}_{x}(\mathrm{C},\ f)$, either as in (62a) or as in (62b):[17]

(62) (a.) **One-place Eventuality functions**:

$$\boxdot^{\mathrm{S,\,T}}{}_{x}(\mathrm{C}_{\mathrm{X,\,S}},\ f_{\mathrm{X,\,S}})(\sigma) = d$$

iff

(i)	$\mathrm{C}_{\mathrm{X,\,S}}(\sigma)$;	Classifiability
(ii)	$\forall s \in \mathrm{S}_{\sigma},\ t \in \mathrm{T}_{\sigma} f_{\mathrm{X,\,S}}(\text{figure}(\sigma),\ s,\ t) = d$	Homogeneity

(b.) **Two-place eventuality functions**:

$$\boxdot^{\mathrm{S,\,T}}{}_{x}(\mathrm{C}_{\mathrm{X,\,S}},\ f_{\mathrm{X,\,S}})(\sigma)(i) = d$$

iff

(i)	$\mathrm{C}_{\mathrm{X,\,S}}(\sigma)$;	Classifiability
(ii)	$f_{\mathrm{X,\,S}}(\text{figure}(\sigma))(i) = d$	Homogeneity

[16] As far as I know, there are no clear cases of analagous adjectives, adjectives with measure functions that vary while the eventuality type is kept fixed.

[17] Given that both the state-function and the measure-function exist in this analysis, one is in principle free to use the measure function as the denotation of the adjective and reserve the state function as a kind of intermediary step in the derivation of the verb meaning. For example, INCREASE could be an operator on measure functions (as HKL have it), with the additional argument of a classificatory predicate on states. The challenge for this approach is to account for various adverbial modifiers common to the adjective and verb:

(i) The road widened from X to Y.
(ii) The road was 10 feet wide from X to Y.

I believe the account here naturally accommodates these and makes clear the semantic differences and similarities. There are also other kinds of adverbial modifiers appropriate for the adjective, for example, *an unbelieveably deep canyon*. It is not 2500 feet (the actual depth of the canyon) which is unbelievable, but the fact that this entity (the canyon) is that deep. This might of course be handled by treating *unbelievably* as a function from measure functions to measure functions, but it appears to work in exactly the same way for verbs (*The canyon deepened unbelievably*). Thus, the challenge is to give a uniform analysis, while still maintaining that verbs and adjectives differ in whether they use eventualities.

Both alternatives assume states are eventualities σ classifiable by a state-predicate C with a *figure* role to which a measure-function f_{S} applies. In both alternatives, criterion (i) amounts to the requirement that σ is classifiable by some relevant state predicate C as being a C-eventuality. In alternative (a), labeled *one-place eventuality functions*, we eliminate the time and space indices of the measure function with a **homogeneity requirement**, that is, by requiring that all indices in the trace of σ return the same value. In alternative (b), we *index* the eventuality functions by defining a two-place function of an eventuality and an index.

In this paper I have pursued one-place eventuality functions, contra Gawron (2005), which adopts two-place eventuality functions.[18] Under alternative (a), there is a single denotation for the adjective *wide* that is a one-place function from states of affairs to degrees.

$$\textbf{wide}_{\mathrm{S,T}}(\sigma) = d$$

Under (b), there is a single underspecified rule licensing an underspecified functor that has both spatially indexed functions and temporally indexed functions in its extension. That is we can have both (a) and (b)

(a) $\mathrm{wide}(\sigma)(t) = d$
(b) $\mathrm{wide}(\sigma)(s) = d$

There are two reasons to favor one-place eventuality functions.

First, the analysis of Gawron (2005) is forced to assume that any particular *reading* for an extent adjectives is either temporally indexed or spatially indexed. Thus any use of an adjective like *wide* denotes either a function from eventualities and spatial indices to degrees, presumably invoked in (63a), or a temporally indexed function from eventualities and times to degrees, presumably invoked in (63b). The problem is what to say about (63c):

(63) a. The river was 18 feet wide at three'o'clock.
b. The river was 18 feet wide at the ford.
c. The river was 18 feet wide at three'o'clock at the ford.

Is (63c) ambiguous, or is a third, doubly indexed measure-function invoked? One-place eventuality functions allow us to dispense with this distinction. There is one function taking an eventuality as its argument; that eventuality — call it a state — has both spatial and temporal extent, like most eventualities. This state is required to be "small enough" so that all indices, temporal and spatial, return the same value for the relevant measure function.

The other argument for alternative (a) can be made by the following observation: There are perfectly well-defined widening events for which the width of the figure is undefined at both the beginning and end of the event. Consider (64):

(64) a. The crack$_c$ widened$_e$ 5 millimeters.
b. Assume that at the start of event e, crack$_c$ already has varying width.

[18] In that respect, he follows Hay et al. (1999).

For example, suppose that at time e_{START}, the crack is 1 centimeter wide at one end and 3 centimeters wide at the other. Suppose the crack widens 5 millimeters everywhere. I think (64a) is true in these circumstances. However, I also think the width of the crack is undefined throughout e. When we say a crack is 1 centimeter wide at time t, that is shorthand for saying all the contextually relevant width measurements of the crack come to 1 centimeter (within current standards of precision). When the relevant measurements disagree by more than current standards of precision allow, the crack has no well-defined width.

What this example shows is that a two-place temporally indexed state-function is insufficient to handle all cases of event readings. For concreteness consider the version of (47) used in Gawron (2005):

(65)
$$\forall t_1, t_2, x, d \left[\begin{array}{l} \exists e\, [\ \text{increase}(\text{wide})(e) = d \wedge \\ \qquad \text{START}(e) = t_1 \wedge \text{END}(e) = t_2 \wedge \textit{figure}(e) = x\,] \\ \qquad\qquad\qquad \longleftrightarrow \\ \quad \exists \sigma_1, \sigma_2 [\ \text{START}(\sigma_1) = t_1 \wedge \text{END}(\sigma_2) = t_2 \wedge \\ \qquad\qquad \textit{figure}(\sigma_1) = \textit{figure}(\sigma_2) = x \wedge \\ \qquad\qquad \text{wide}(\sigma_1)(t_2) = \text{wide}(\sigma_2)(t_1) + d\,] \end{array} \right.$$

A glance at the two-place state functions on the right hand side shows that in order for a widening event to be defined, the following starting and ending states must be defined:

$$\begin{array}{c} \text{wide}(\sigma_1)(t_2) \\ \text{wide}(\sigma_2)(t_1) \end{array}$$

And these are in turn defined so that the width of the entire figure must be defined at times t_1 and t_2.

Clearly, the circumstances just considered for example (64) show that this is asking too much. Only the width of *parts* of the figure need to be defined at the start and end times, and the measures of some of these parts need to widen by the specified amount.

Axiom (47) differs from (65) in that it assumes width-states that can be arbitrarily tailored to both subparts of the figure and to subintervals of time, which allows states small enough to be felicitous for examples like (64).[19]

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[19] The very same example with a slightly amended set of facts also suggests a refinement of (47). Suppose that the crack in (64a) in fact underwent no change at all. An event reading of (64a) would come out true, according to Axiom (47), because we could compare the measure of one part of c at the beginning of e with another 2-centimeter wider part at the end of e. Clearly the measures being compared at the start and end of the event need to belong to the same parts. The following amendment fixes this by introducing the idea of axial projection (Compare (Jackendoff 1996), who introduces a similar notion for somewhat different reasons).

$$\forall d, e \left[\begin{array}{c} \text{INCREASE}_\alpha\,(\mathbf{wide}_{\alpha,\beta})(e) = d \\ \longleftrightarrow \\ \exists \sigma_1, \sigma_2\, [\text{PROJECT}_\alpha(e, \mathbf{wide}_{\alpha,\beta}, \sigma_1, \sigma_2) \wedge \\ \quad \mathbf{wide}_{\alpha,\beta}(\sigma_1) = \mathbf{wide}_{\alpha,\beta}(\sigma_2) + d\,] \end{array} \right]$$

Here PROJECT selects starting and ending width states, as before, with the additional requirement that their spatial coordinates be the same, that is, that they be endpoints of a projection through time of a part

In this section, I have argued for the introduction of states into the semantics of adjectives, a move which is critical to the particular analysis of degree achievements I have adopted. We have also filled in some of the details for the analysis of *wide* and *widen*. For the cases discussed thus far, we have the following picture:

(66)

wide$_{\text{S,T}}$	A state function homogeneous on both S and T. S can be a reference axis.
INCREASE_α (**wide**$_{\text{S,T}}$)	A dynamic predicate underspecified for its axis of change. When α is T, accounts for event readings of *widen*. When α is a reference axis S, accounts for extent readings.

Left out of the discussion thus far is the possibility of examples like (28d), in which the axis is not a reference axis, and an extent reading is impossible. In the following sections, we flesh out the details for other extent predicates and non-canonical uses of *widen* like that in (28d).

2.3 Extend and cover

We next discuss the extension of the analysis sketched in Section 2.1 and 2.2 to the cases of *extend* and *cover*.

We will follow the method used with *wide*. That is, a state function will be defined in terms of an underlying measure function. However, the state operator ${\boxdot^{\text{S, T}}}_x$will not be suitable for defining the state function for *extend*. Consider the the homogeneity requirement ${\boxdot^{\text{S, T}}}_x$ imposes on its measure function f:

(67) $\forall t \in \text{T}_\sigma,\ s \in \text{S}_\sigma f_{\text{X,S}}(\text{figure}(\sigma), t, s) = d$

The path phrases we find with *extend* show that it lexically selects a context axis S that points in the direction of the axis of measurement X. However, we have explained a number of constraints on extent readings with the assumption that distance measure functions cannot take a value at a point on an axis that is oriented in the same direction as the measurement. Therefore, for every s on such an S, such an f is undefined, and the above homogeneity requirement cannot be met. How then to proceed with *extend*?

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of the event.

$\text{PROJECT}_\alpha\ (e,\ \text{wide}^{\text{S}}_{\text{T}},\ \sigma_1,\ \sigma_2)$ iff
(a) $\sigma_1, \sigma_2 \sqsubseteq e$;
(b) $\text{START}_\alpha(\sigma_1) = \text{START}_\alpha(e)$;
(c) $\text{END}_\alpha(\sigma_2) = \text{END}_\alpha(e)$;
(d) $\text{figure}(\sigma) = \text{figure}(e)$;
(e) $\beta_{\sigma_1} = \beta_{\sigma_2}$

This largely tracks the definition of the START and END relations in (47). The innovation is clause (e). When $\alpha = \text{T}$, this makes $\text{S}_{\sigma_1} = \text{S}_{\sigma_2}$, which means start and end states σ_1 and σ_2 return measures of the same part of the figure. When $\alpha = \text{S}$, this makes the start and end states have the same temporal trace.

In fact, the ground assumptions about distance measurements along a non-reference axis, spelled out in (54), preclude only positive values *at a point* on the axis. Measurement along the measurement axis is still possible over intervals. Thus, the solution is to begin with a measure function defined on spatial intervals.

(68) $\text{extend}^{-}_{\text{S}} : \text{I} \times \text{SI} \times \text{T} \rightarrow \text{D}$
$(x,\ [s_0,\ s_1],\ t) \mapsto \text{span}^{-}_{\text{S}}(\text{path}^{-}_{\text{S}}(x,\ [s_0,\ s_1],\ t)\ )$

Here the domain and range are as follows:

I	the set of individuals
SI	the set of intervals spatial axis S
T	the set of times
D	the set of distances

The properties of the function path^{-} will be discussed in the next section. What

$$\text{path}^{-}_{\text{S}}(x,\ [s_1,\ s_2],\ t)$$

returns is the spatial region entity x occupies at time t for the spatial interval between s_1 and s_2, in other words, the portion of x lying between s_1 and s_2. $\text{span}^{-}_{\text{S}}$ in turn measures the distance of this spatial region along S. In sum the definition in (68) says that

$$\text{extend}^{-}_{\text{S}}(x,\ [s_0,\ s_1],\ t)$$

returns the length (at time t) of x for the portion of x lying between s_1 and s_2.

Then the result we want for the state function of *extend* is:

(69) $\textbf{extend}^{\text{S}}_{\text{T}}(\sigma) = d$ only if
$\forall t[\text{extend}^{-}_{\text{S}}(\text{figure}(\sigma),\ [\text{START}_{\text{S}}(\sigma), \text{END}_{\text{S}}(\sigma)],\ t) = d]$

Rather than universally quantifying over both spatial index s and temporal index t as $\textbf{wide}_{\text{S,T}}$ does, the definition of $\textbf{extend}^{\text{S}}_{\text{T}}$ quantifies only over t.

Of course, the definition in (69) cannot be achieved using operator used to define the state function for $\textbf{wide}_{\text{S,T}}$, because of the homogeneity condition in (67). Thus *extend* will be defined via a new operator notated $\oplus^{\text{S}}\boxdot^{\text{T}}{}_{x}$:

(70) $$\oplus^{\text{S}}\boxdot^{\text{T}}{}_{x}(\text{C},\ f_{\text{S}})(\sigma) = d$$
iff

(i)	$\text{C}(\sigma)$;	Classifiability
(ii)	$\forall t \in \text{T}_{\sigma} f_{\text{S}}(\text{figure}(\sigma),\ [\text{START}_{\text{S}}(\sigma), \text{END}_{\text{S}}(\sigma)],\ t) = d$	Temporal Homogeneity

The intuition here is that $\oplus^{\text{S}}\boxdot^{\text{T}}{}_{x}$is used for any measure function that is irreducibly a function of spatial intervals. Instead of quantifying over spatial indices, what this definition does is use an interval on S to construct a degreeable property of an eventuality defined on that interval.

The notational generalization is that $\boxdot^{\alpha}$is used when α indices are universally quantified over, because $\boxdot$ is reminiscent of modal operator $\Box$, used when worlds are universally quantified over. On the other hand, the component $\oplus^{\alpha}$is used when the indices of axis α are "summed" into an interval.

Using this operator, the official definition of the eventuality function for *extend* is:

(71) $\textbf{extend}^{\mathrm{S}}_{\mathrm{T}} = \oplus^{\mathrm{S}}\boxdot^{\mathrm{T}}{}_{x}(\text{extending}_{\mathrm{S}},\ \text{extend}^{-}{}_{\mathrm{S}})$

Here *extending* is the classifying predicate for extending eventualities and extend^{-} is the distance-based measure function defined in the previous section.

Summarizing, the $\boxdot^{\mathrm{S,\,T}}{}_{x}$operator used for *wide* produces eventuality functions that are homogeneous along both axes S and T; the $\oplus^{\mathrm{S}}\boxdot^{\mathrm{T}}{}_{x}$operator produces eventuality functions that are homogeneous along axis T, but not along axis S. I will call such eventuality functions **dimorphic**.

> Eventuality functions defined via the the $\oplus^{\mathrm{S}}\boxdot^{\mathrm{T}}{}_{x}$operator are **dimorphic** in that their axial degreeable extent properties that are homogeneous along the time axis but not along their spatial axis.

Only the axes on which an eventuality function is homogeneous are subscripted. Thus, the difference in subscripting between $\textbf{extend}^{\mathrm{S}}_{\mathrm{T}}$ and $\textbf{wide}_{\mathrm{S,T}}$ reflects the difference in their homogeneity constraints. It is now possible to be explicit about what distinguishes state functions from eventuality functions. The notion state function is axis-relative. All state functions of axis α are homogeneous along α . It is a generalization about adjectives that they are all homogeneous along the temporal axis; but, it appears that there are dimorphic adjectives. The paradigm examples is *full* (the fullness of a flask cannot be measured at any point along the depth axis, for all the same reasons given for *cover*). Other candidates would include shape adjectives: *circular*, *oval*, *square*, *jagged* (deverbal?); pattern identifiers: *paisley*, *polka-dotted* (deverbal?), *flecked* (deverbal?), and so on. Although all clearly describe "global" spatial properties hard to define at a point on an axis, the axiality of all these adjectives is questionable. I would assume dimorphism is marked for adjectives.

The function $\textbf{extend}^{\mathrm{S}}_{\mathrm{T}}$ as defined in (71) is temporally homogeneous and thus only accounts for extent readings of the verb. As indicated in the introduction, the event readings for *extend* will be derived using the operator INCREASE.

$$\textbf{extend-event}^{\mathrm{S,T}} = \text{INCREASE}_{\mathrm{T}}(\textbf{extend}^{\mathrm{S}}_{\mathrm{T}})$$

The new eventuality function, $\textbf{extend-event}^{\mathrm{S,T}}$, is homogeneous along neither axis.

The descriptive fact to capture about *extend* is that it has no derived spatial dynamic version. That is, $\text{INCREASE}_{\mathrm{S}}$ does not combine with $\textbf{extend}^{\mathrm{S}}_{\mathrm{T}}$:

(72) $*\text{INCREASE}_{\mathrm{S}}(\textbf{extend}^{\mathrm{S}}_{\mathrm{T}})$

At this point, it is possible to be explicit about why not. We impose the following constraint:

(73) Homogeneity Constraint

$*\text{INCREASE}_\alpha \ldots f^\alpha \ \ldots$

The intuition is quite simple: INCREASE_α should combine only with eventuality functions that are homogeneous along α and superscripted axes are those for which the function is not homogeneous. Intuitively, this is because INCREASE_α should combine only with α -states, and homogeneity is diagnostic of states. So much is consistent with nearly everyone's pictures of states. The Homogeneity Constraint will have two practical effects. First, of all, we make no type theoretic distinctions between state functions like $\mathbf{wide}_{\mathrm{S,T}}$ and event functions like $\text{INCREASE}_{\mathrm{T}}(\mathbf{wide}_{\mathrm{S,T}})$; both are functions from eventualities to degrees. The Homogeneity Principle will prevent $\text{INCREASE}_{\mathrm{T}}$ from applying to dynamic predicates like $\mathbf{widen}^{\mathrm{S}}_{\mathrm{T}}$ (= $\text{INCREASE}_{\mathrm{T}}(\mathbf{wide}_{\mathrm{S,T}})$), because they are not homogeneous along T. As desired for *extend*, it will also block application to eventuality functions defined for a non-referential spatial axis, blocking (72).

This leaves us with the following picture for *extend*:

(74)

[−Dynamic]	[+Dynamic]
$\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}}$	$\text{INCREASE}_{\mathrm{T}}(\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}})$

By way of contrast with *extend*, we consider the case of *cover*. There are a number of possibilities for the range of the measure function for *cover*, among them area measures, regions of space, and real numbers between 0 and 1. As it happens the choice between these will not matter for the arguments being made here, but, for concreteness, we will choose the last possibility, defining the range as a dimensionless ratio between two areas, the area covered (the entire range of surface contact between two participants x and y), and the area that could be covered (the surface area of participant y over some interval of an axis S):

$$\begin{aligned} \text{cover}^{-}_{\mathrm{S,R}}: \quad & \mathrm{I} \times \mathrm{SI} \times \mathrm{T} \longrightarrow (0,\ 1] \\ & (x,\ y,\ [s_o,\ s_1],\ t) \mapsto \frac{\text{Area}(\text{ON/OVER}_{\mathrm{R}}(x, y, t))}{\text{Area}(\text{SURFACE}(y, [s_o, s_1]))} \end{aligned}$$

There is an extra spatial axis, R, in this definition which is needed for the occlusion sense of *cover* (which uses the spatial relation OVER in place of ON). I return to this sense and the additional axis below. For now, the main axis of interest is S. For *cover*, as for *extend*, the measure function is defined for intervals on S; as with *cover*, this leads to a state-function that is temporally, but not spatially, homogeneous.

The main difference in the derivation of the two state functions is that the measure function for *cover* takes an extra argument, the *ground*. This requires an operator like the one for *extend*, except that it accommodates the extra participant.

$$\oplus^{\mathrm{S}}\boxdot^{\mathrm{T}}{}_{x,y}(\mathrm{C}_{\mathrm{S}},\ f_{\mathrm{S}})(y)(\sigma) = d$$

iff

$$\boxed{\begin{array}{ll} \text{(i)} & \mathrm{C}_{\mathrm{S}}(\sigma); \\ \text{(ii)} & \forall t \in \mathrm{T}_\sigma f_{\mathrm{S}}(\text{figure}(\sigma),\ \text{ground}(\sigma),\ [\text{START}_{\mathrm{S}}(\sigma), \text{END}_{\mathrm{S}}(\sigma)],\ t) = d \end{array}}$$

The idea is that a denotation like $\mathbf{cover}^{\mathrm{S}}_{\mathrm{T}}$ is really of a different type than ordinary eventuality functions like $\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}}$: It is a function from individuals to eventuality functions.

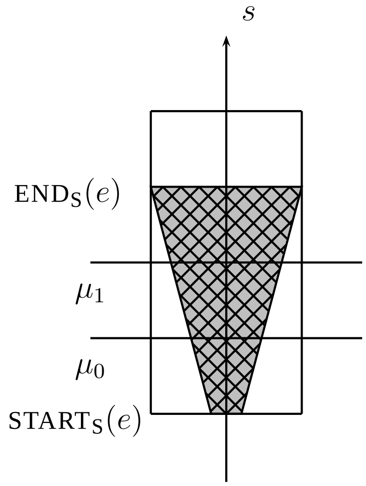

Figure 4: Driveway with varying leaf cover

In effect each ground defines a different scaling of the measures being assigned to the figure.[20]

So we can rewrite the definition of $\mathbf{cover}^{\mathrm{S}}_{\mathrm{T}}$ as:

(75) ${}_{\mathrm{R}}\mathbf{cover}^{\mathrm{S}}_{\mathrm{T}}(y)(\sigma) = d$ iff $\oplus^{\mathrm{S}}\boxdot^{\mathrm{T}}{}_{x,y}(\text{covering}_{\mathrm{S,R}},\ \mathbf{cover}^{-}_{\mathrm{S,R}})(y)(\sigma) = d$

Here the extra axis R has simply been notated as a prefix, since it is neither a homogeneous spatial axis like that of *wide*, nor a path axis like S. For readability, we wil ignore it, except where needed.

Some examples of covering measurements are given in Figure 4, which shows (rather schematically) a covering measurement at lines μ_0 and μ_1 for a driveway with varying leaf cover. If l is the the leaves, and d is the driveway, and t is the time of the picture in Figure 4,

$$\mathbf{cover}^{-}_{\mathrm{S}}{}_{\mathrm{S},\mu_0}(d,\ l,\ [\mu_0,\ \mu_1],$$

returns the ratio of the area of the shaded trapezoid between μ_0 and μ_1 to the area of the entire rectangle between μ_0 and μ_1. If eventuality e "starts" (according to axis S) at the base of the driveway (bottom of figure) and ends at an arbitrary point called END$_{\mathrm{S}}$(e), the cover-measurement for e is ratio of the area of the shaded region to the area of the entire rectangle beginning at START$_{\mathrm{S}}$(e) and ending at END$_{\mathrm{S}}$(e).

As with *extend*, the event readings for *cover* will be derived via INCREASE. To satisfy the type requirements of INCREASE$_{\alpha}$, the ground argument must be fed in first:

$$\mathbf{cover\text{-}event}^{\mathrm{S,T}} = \mathrm{INCREASE}_{\mathrm{T}} \circ \mathbf{cover}^{\mathrm{S}}_{\mathrm{T}}$$

Therefore,

$$\mathbf{cover\text{-}event}^{\mathrm{S,T}}(y)(\sigma) = \mathrm{INCREASE}_{\mathrm{T}}(\mathbf{cover}^{\mathrm{S}}_{\mathrm{T}}(y))(\sigma)$$

With *cover* there is, however, a wrinkle that does not arise for *extend*. With the right axis, as we saw in (30b), in the introduction, *cover* may have have spatially dynamic readings with graduality. There are two possible accounts. First, in addition to a predicate defined with $\oplus^{\mathrm{S}}\boxdot^{\mathrm{T}}{}_{x}$, there might be another defined with $\boxdot^{\mathrm{S,\,T}}{}_{x}$, the same

[20]Thus, the treatment of *ground* here is consistent with intuition of Dowty (1991) that the ground is the incremental theme, and that of Tenny (1994) that it "measures out" the event. The metaphor is quite close to Tenny's, since the ground literally defines the scale.

operator used for *wide*. That is, using R for the reference axis in (30b), we would have (76):

(76) $\mathbf{cover}_{\mathrm{R,T}} = \oplus^{\mathrm{R}}\boxdot^{\mathrm{T}}{}_{x,y}(\mathrm{covering}_{\mathrm{R}},\ \mathrm{cover}^{-}_{\mathrm{R}})$

However, we saw in (32), repeated here, that path phrases with *cover*, even in spatially dynamic cases, needed to exploit an axis in the plane of the ground's surface.

(77) The aneurysm grew as it approached the valve and gradually covered it from end to end.

The phrase *end to end* must refer to ends of the valve. This suggests that the lexically preferred ground-surface axis is not being overruled in this example. Rather, what we have is:

(78) $\textsc{increase}_{\mathrm{R}} \circ {}_{\mathrm{R}}\mathbf{cover}^{\mathrm{S}}_{\mathrm{T}}$

Note that this is not a violation of the homogeneity constraint because R and S are different. Rather, what is odd here is that $\textsc{increase}_{\mathrm{R}}$ is not using the predicate's context axis S.

One may well ask why such a novel axis is possible. The answer is, I believe, that this is the same axis R introduced by the occlusion sense of *cover*. Because the spatial relation between the figure and ground is OVER rather than ON, a line-of-sight axis determining the line centering the figure over the ground becomes available. As a default perhaps, that axis is a vertical axis (*the clouds covered the city*), but it needn't be:

(79) From these seats, the center column covers almost all of the right half of the stage.

What happens in (30b) is that the amount of coverage is simply defined by a projection of the figure onto the ground along the line of site R; because of this, coverage can vary along the axis and it becomes an axis of reference, usable as an axis of change.

Then, the full picture for *cover* looks like this:

(80)

[−Dynamic]	[+Dynamic]
${}_{\mathrm{R}}\mathbf{cover}^{\mathrm{S}}_{\mathrm{T}}$	$\textsc{increase}_{\mathrm{R}} \circ {}_{\mathrm{R}}\mathbf{cover}^{\mathrm{S}}_{\mathrm{T}},\ \textsc{increase}_{\mathrm{T}} \circ {}_{\mathrm{R}}\mathbf{cover}^{\mathrm{S}}_{\mathrm{T}}$

3 Paths and extent readings

We noted in Section 1 that extent predicates co-occur with path-phrases. In fact, path phrases with stative non-motion readings were used to define extent predicates.

As noted in Section 2.1, two kinds of path-phrases co-occur with event readings of extent verbs, those that are incremental themes (in the sense of Dowty 1991) and those that are not:

(81) (a) Incremental paths: The truth conditions require that the path covered grow homomorphically with the event, with the location identified in the *from* phrase overlapped at the beginning of the event, and the location identified in the *to*-phrase overlapped at the end. Incremental paths entail motion.

(b) non-incremental paths. These paths occur when some *part* of the theme is involved in the event, typically with themes large enough for their parts to change in different ways.

The descriptive differences are illustrated in (82). The readings of interest in all cases are event readings:

(82) Incrementality

[+ Incr_e]	(a)	A storm front crossed from Prescott to the border.
	(b)	The fog extended from the pier to the point.
[- Incr_e]	(c)	The crack widened from the tower to the north gate.
	(d)	Fog covered the peninsula from the pier to the point

First, for the cases marked [- Incr_e], the paths are not necessarily incremental themes. For example, in (d) the fog's progress may be in any order as long as in the end a span between pier and point is covered. Second, for the non-incremental case there is no movement entailed. There is no sense in which the crack or the fog in (c) and (d) have to change location. The crack may appear everywhere along the indicated path simultaneously, as long as it is widening. The fog, as it often does, may simply condense in place, thickening over the course of the event.

In contrast, the [+ Incr] versions of (82) do entail motion. The region described by the *from* phrase must overlap with the figure at the beginning of the event, and the region described by the *to*-phrase at the end.

This sets up us two major questions about the distribution of path phrases:

(83) a. What set of predicates selects for path phrases?
b. Among those, what determines the choice between incremental and non-incremental paths?

We will account for the two kinds of path-phrases by positing that path phrases are axially underpsecified in a way that parallels the axial ambiguity of extent predicates like *widen*. That is, there will be **temporally indexed paths** that track the location of a figure over time and capture incremental readings, and there will be **spatially indexed paths** that track the location of parts of a figure over space. Temporally indexed paths will be welcomed by environments that entail motion, while spatially indexed paths will be incompatible with such entailments. Thus, the temporally indexed paths will account for incremental paths, and the spatially indexed paths for non-incremental paths.

We begin by defining an operator $\mathtt{path}$ which, for each appropriate event, will return the eventuality function that tracks the location of the event's *figure* with respect to either space or time.

3.1 Path operator and events

I will write

$$\textbf{path}(e)$$

to denote the path associated with event e, if e is an event of the appropriate type.[21]

I model paths as functions, though everything assumed here could be reworked for other models of paths, including paths as primitives in the ontology. suitably axiomatized as in Krifka (1998). Obviously, the appeal of taking this road is that the parallelism between underspecified eventuality functions like $\mathbf{wide}^{\mathrm{S,T}}$ and underspecified path functions is strengthened.

$$\mathbf{path}(e) = \pi$$

I use π here for a function from times to locations of the figure of e[22] Normally if the location of the figure of e at time t is l, I simply write:

(84) $\mathbf{path}_{\mathrm{T}}(e)(t) = l.$

The key property of path functions for our purposes is that they are always defined relative to an axis. Thus (84) is a temporally indexed path, while

(85) $\mathbf{path}_{\mathrm{S}}(e)(s) = l$

is a spatially indexed path. The expression in (85) also returns a location of the figure, but a location restricted to that slice of the figure that intersects the plane through axis S at s. A more explicit version of the definitions of the two path operators is given in the Appendix B. The key point is that both are defined in terms of an eventuality independent $\mathbf{path}^{-}_{\mathrm{S}}$ function, parallel to the way eventuality functions for adjectives are defined in terms of eventuality-independent measure functions:

(a) $\mathbf{path}^{\mathrm{S}}_{\mathrm{T}}(e)(t) = l \quad \text{path}^{-}(\text{figure}(e),\ [\textsc{start}_{\mathrm{S}}(e),\ \textsc{end}_{\mathrm{S}}(e)], t) = l$
(b) $\mathbf{path}_{\mathrm{S}}(e)(s) = l \quad \forall t \in \mathrm{T}_e \text{path}^{-}(\text{figure}(e),\ s,\ t\ ) = l$

The definitions are asymmetric: (a) $\mathbf{path}_{\mathrm{T}}$(e)(t) is defined to given the location of the figure over an interval on S at a time t; (b) $\mathbf{path}_{\mathrm{S}}(\sigma)$(s) is defined only when the same location is occupied by each slice for the entire duration of e. Thus, $\mathbf{path}_{\mathrm{S}}$ is homogeneous for time in a way analogous to the way $\mathbf{wide}_{\mathrm{S,T}}$ was. This will make it incompatible with motion along axis S. On the other hand, $\mathbf{path}_{\mathrm{T}}$ is not incompatible with stasis. The effect of this asymmetry is the following. Axial predicates will select for path indiscriminately, not choosing between $\mathbf{path}_{\mathrm{S}}$ and $\mathbf{path}^{\mathrm{S}}_{\mathrm{T}}$. When motion is entailed $\mathbf{path}_{\mathrm{S}}$ will be ruled out. This will make $\mathbf{path}^{\mathrm{S}}_{\mathrm{T}}$ the only possibility. When motion is not entailed, both $\mathbf{path}_{\mathrm{S}}$ and $\mathbf{path}^{\mathrm{S}}_{\mathrm{T}}$ will be possible; I will argue that this is harmless.

A few remarks on the partiality of path functions are in order. For any path function π, whether temporal or spatial, The domain is that set of points on the relevant axis α that fall within e:[23]

$$\mathbf{path}_{\alpha}(e) = \pi \quad \text{only if} \quad \pi : [\textsc{start}_{\alpha}(e),\ \textsc{end}_{\alpha}(e)] \rightarrow \text{Locations}$$

[21] I assume event classification predicates like *width* in (59) are sortal predicates true of events belonging to **event sorts** and that these sorts have role signatures. Among other things **path** is a role appropriate for eventualities of a certain sort.

[22] This is the kind of path function assumed in Verkuyl (1978) and Verkuyl (1993).

[23] See the appendix for the full definitions of temporal and spatial path functions. Here

$$[\textsc{start}_{\mathrm{T}}(e),\ \textsc{end}_{\mathrm{T}}(e)]$$

is another way of notating what I have been writing T_e.

Thus, there are many path functions for any given event, corresponding to the starts and ends determined by each axis through it. Crucially the domain of the path functioon corresponds to the boundaries of the event along the relevant axis. Thus, path phrases (which denote properties of path functions) constrain not just the direction of an axis, but also the boundaries of events, the starts and ends along either temporal or spatial axes.

In Section 1, I defined an axial predicate as one that selected path phrases. I will formalize this definition with the following **Path-Axis Principle** (PAP):

> **Path-Axis Principle** (PAP)
> All and only only axial verbs, adjectives, and prepositions have the role $\mathbf{path}_\alpha$ in their role signature. It also follows that all and only such predicates have the role *figure* in their signature.

Technically the PAP follows from the definition of the path role in (104a) in the appendix. The essential idea is that path selection and axiality are the same. Path phrases are the primary linguistic device for orienting axes; and this is what explains their correlation with event-extent readings.

3.2 Paths and their distribution

In this section we illustrate how temporally and spatially indexed paths (TIPs and SIPs) account for incremental and non-incremental paths respectively. We begin with the question of how the definition of path interacts with the analyses of *wide* and *widen*.

First, as noted in Section 2.1, paths occur with the adjective *wide* as well as with the degree achievement verb, indicating that an axis is being exploited by both:

(86) a. The canyon was six feet wide from the North End$_\mathrm{n}$ to the trail head$_\mathrm{t}$.
b. The canyon widened six feet from the North End$_\mathrm{n}$ to the trail head$_\mathrm{t}$.

Sentence (a) asserts the existence of a width state at some past time whose minimum on the S-axis overlapped n (the North End) and whose maximum on the S-axis overlapped t (the trail head), and whose measure value for wide is 6 feet; ambiguous sentence (b) asserts either the existence of a widening state over the same spatial span or the existence of a widening event over some temporal span, but over that same spatial span.

I will now show by working through this pair of examples that the truth-conditions of spatially and temporally indexed path operators account for incremental and non-incremental path phrases. I assume the semantics of (86a) and (86b) are something along the lines of (87):

(87) a. $\exists\sigma[\mathbf{wide}_{\mathrm{S,T}}(\sigma) = [6\text{ ft}] \wedge \textit{figure}(\sigma) = c \wedge [n : h] \circ \mathbf{path}_{\mathrm{S}}(\sigma)]$
b. $\exists\sigma[\textsc{increase}_\alpha(\mathbf{wide}_{\mathrm{S,T}})(\sigma) = [6\text{ ft}] \wedge \textit{figure}(\sigma) = c \wedge [n : h] \circ \mathbf{path}_{\mathrm{S}}(\sigma)]$

Consider (a). This semantics assumes $[n : h]$ is a property true of those paths whose minimum overlaps n (the north end) and whose maximum overlaps h (the trail head).

Since this path is a path along axis S, the minima and maxima will be on axis S. Since the path boundaries and event boundaries coincide on S, this entails an event bounded in such a way as to include only the parts of the canyon falling between those points, and since the width measure in (a) along S is homogeneous, the measure along all those points must be 6 feet. Similarly, at any t in T_σ, the width measure must be 6 feet; and for any such t,

$$\mathbf{path}^{-}_{\mathrm{S}}(\text{figure}(\sigma),\ \textsc{start}(\sigma),\ t)$$

overlaps the north end of the trail.

Next consider (b), which is an underspecified semantics for both the event and extent readings. The path phrase for both readings uses the spatial axis S. On the event reading, what this means is that the start and end of the event along S satisfy the constraints imposed by the path phrases, just as they do with the state in (a). Taken together with the truth conditions for *widen*, this means the extent of the figure between the start and end of S must undergo widening, and the increase in width must be in the direction of S. Thus the width must be narrower at the north end and wider at the trail head end. Although S imposes corresponding spatial orderings on the direction of widening and on the North gate and tower, there is no ordering imposed on the temporal progression of the widening. Thus, the semantics in (87b) captures two important one important facts discussed in Section 1. First, the path phrase on the event reading is not incremental. Second, the widening must be compatible with the directionality of axis S.

The Path Axis Principle guarantees that *wide* and *widen* select for **path**. Thus nothing rules out readings for (87) which use $\mathbf{path}^{\mathrm{S}}_{\mathrm{T}}$. What this predicts is the possibility of an incremental path reading for (b), that is, a reading on which the widening temporally progresses from the north end to the trail head. This reading is difficult to establish since its truth conditions are strictly stronger than the non incremental reading discussed above, but the possibility of such seems to be promoted when *gradually* is added. In other words, the widening itself may be gradual, or the progression from north end to trail head may be.

Consider again (1a), repeated here. The proposed semantics for extent and event readings are given in (b) and (c):

(88) a. The fog extended (from the pier to the point).
b. $\exists\sigma[\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}}(\sigma) = \textsc{max}_\sigma \wedge \textit{figure}(\sigma) = f\ \wedge [\text{pier : point}] \circ \mathbf{path}_{\mathrm{S}}(\sigma)]$
c. $\exists e[\textsc{increase}_{\mathrm{T}}(\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}})(e) = \textsc{max}_e \wedge \textit{figure}(e) = f \wedge [\text{pier : point}] \circ \mathbf{path}_{\mathrm{T}}(e)]$

Note that the extent reading in depicted in (b) uses a spatially- indexed path, while the event-reading depicted in (c) uses a temporally-indexed path. According to the semantics in (b) and (c), the alternation between event and extent readings of *extend* correlates with the use of temporally-indexed and spatially indexed paths.

The extent reading in (b) works exactly as the extent reading of *wide* did. The path of the figure must begin at the pier and end at the point on S, and its extent measure must be consistent. Again $\mathbf{path}^{\mathrm{S}}_{\mathrm{T}}$ is possible, and again, this is harmless, because the homogeneity condition on $\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}}$ precludes motion.

The semantics in (c) gives the event reading with the incremental reading for the path phrase. Truth-conditionally, this works as follows. The $\textsc{increase}_{\mathrm{T}}$ operator guarantees there has been been a positive increase in length over the course of time.[24] Since e extends in the direction of the increasing length, motion along S is entailed. Therefore, $\mathbf{path}_{\mathrm{S}}$ is precluded; only $\mathbf{path}^{\mathrm{S}}_{\mathrm{T}}$ works, and $\mathbf{path}^{\mathrm{S}}_{\mathrm{T}}$ requires that at the temporal start of e the path of the figure must overlap the pier, at the temporal end, the point. This is the incremental reading.

The distributional question of where incremental paths occur has now been answered. They occur if motion is entailed, but not only if. The assumptions necessary to the account are collected in (89):

(89) a. The Path Axis Principle (PAP), allowing TIPs and SIPs in the role signatures of all axial predicates (including *wide/widen, extend*).

b. $\mathbf{path}_{\mathrm{S}}$ is homogeneous for time the way $\mathbf{wide}_{\mathrm{S,T}}$ was. This will make it incompatible with motion along axis S.

The upshot of these assumptions is that incremental paths occur if motion is entailed.[25]

Such an account says that the reason $\textsc{increase}_{\mathrm{T}}(\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}})$ takes incremental paths and $\textsc{increase}_{\mathrm{T}}(\mathbf{wide}_{\mathrm{S,T}})$ does not is not a matter of role signature but of entailment; $\textsc{increase}_{\mathrm{T}}(\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}})$ and $\textsc{increase}_{\mathrm{T}}(\mathbf{wide}_{\mathrm{S,T}})$ have the same role signature; however, because of the definition of the measure functions, when $\textsc{increase}_{\mathrm{T}}$ is added to $\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}}$, the result entails motion along the path axis, and when $\textsc{increase}_{\mathrm{T}}$ is added to $\mathbf{wide}_{\mathrm{S,T}}$, it does not. This renders $\textsc{increase}_{\mathrm{T}}(\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}})$ semantically incompatible with SIPs.

Meanwhile, neither $\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}}$ nor $\mathbf{wide}_{\mathrm{S,T}}$ entail motion along the path axis. Therefore, both are semantically compatible with SIPs (and TIPs as well, in a harmless fashion).

The chief benefit of an entailment-based account are that it accounts for variation in motion entailments (and therefore, incrementality of paths) with a single predicate. For example, there do exist cases in which *widen* entails motion along the path axis, as we saw in example (33), discussed in the introduction and repeated here:

(90) The aperture widened from the edge of the door frame to six inches beyond it.

[24]This would seem to leave the following loophole as far as the truth-conditions of extending go. The given truth conditions could be satisfied by an object that increases in length while vacating its starting position at the pier and ending up at the point. This of course would not be extending. But the requirement that the degree of extending be $\textsc{max}_e$ precludes this. Telicity in the HKL analysis is acheived by assigning bounded quantities to degree arguments; such bounded quantities are lexically specific. In this case $\textsc{max}_e$ is the max value the extending function can have for an event of extent $\textsc{end}_{\mathrm{S}} - \textsc{start}_{\mathrm{S}}$ on axis S, which, since extent measures distance along that axis, is exactly $\textsc{end}_{\mathrm{S}} - \textsc{start}_{\mathrm{S}}$. Therefore the figure must extend along S by an amount equal to the size of e, thus overlapping the north end and trailhead. The appendix gives a more detailed discussion of interval sizes on spatial axes.

[25]Within distance measures, distinguish between gap measures (the measure of distance of the gap between two points) and extent measures (the measure of the dimension of the figure along some axis), Then predicates that involve gap measures cannot have extent readings ($\mathbf{path}_{\mathrm{S}}$ gives locations of an extended figure). This would be one way to account for why a verb like *hurtle* has no extent readings:

(i) Clouds hurtled across the sky.

Sentence (i) seems to have no spreading motion reading; incremental motion would be predicted by using $\textsc{increase}_{\mathrm{T}}$ with a gap measure; and that would preclude an extent reading with $\mathbf{S}_{\mathrm{w}}$hen $\textsc{increase}_{\mathrm{T}}$ was omitted.

This example has two properties of interest. First, it has no extent reading. Second, the axis selected by the path phrase coincides with the axis of measurement. Such an axis is not a reference axis, and therefore not usable by $\text{INCREASE}_{\text{S}}$ as an axis of change. This, then, accounts for the lack of an extent reading.

But to account for the event reading in (90), we need to assume there is a stative predicate defined for an axis pointing in the direction of widening which $\text{INCREASE}_{\text{T}}$ can operate on. Using P for this non-reference path axis and for the measure axis, we have:

$$\mathbf{wide}^{\text{P}}_{\text{T}} = \oplus^{\text{P}}\boxdot^{\text{T}}{}_{x}(\text{width}_{\text{P,P}},\ \mathbf{distance}^{-}_{\text{P,P}})$$

This is an alternative denotation for the adjective, defined using $\oplus^{\text{P}}\boxdot^{\text{T}}{}_{x}$, the same operator *extend* used.

This leads to the following complete picture for *widen/widen*, using S for reference axes and P for path axes:

(91)

[−Dynamic]	[+Dynamic]
$\mathbf{wide}_{\text{S,T}},\ \mathbf{wide}^{\text{P}}_{\text{T}}$	$\text{INCREASE}_{\alpha}\ (\mathbf{wide}_{\text{S,T}}),\ \text{INCREASE}_{\text{T}}(\mathbf{wide}^{\text{P}}_{\text{T}})$

Using P as the axis for (90) then accounts for our first property of interest, the fact that there is no extent reading, If we compare this full picture with the full picture for *cover* given in (80), we see they are very similar. The difference between *cover* and *widen* is a matter of which kinds of axes function as defaults for both verbs.

The other property of interest in (90) is that it does in fact entail motion in the relevant sense: Since the increase in width must be an increase in measurement along P there must be motion in the direction of P. This makes *widen* in (90) incompatible with SIPs and compatible with TIPs. On the other hand the use of *widen* in (1b) does not entail motion. The context axis used there does not coincide with the direction of measurement; therefore, an extent reading is possible; and even on the event reading, SIPs are possible.

Summarizing, in this section we have laid out the interaction of the core analysis with the distribution of path phrases. All and only axial predicates allow path phrases. Path phrases divide up into spatially indexed and temporally indexed path phrases, with motion entailments deciding which are chosen by which axial predicates. But motion entailments are axis-sensitive too; thus the choice of axis can determine whether motion is entaled.

4 The case of cross

We turn now to applying the analysis of the previous section to the path shape verb *cross*. The table in (92) summarizes the dimensions of variation among the verbs we have discussed and introduces the features that will characterize *cross*. To begin with, *cover* and *cross* in addition have a second participant *ground* (in addition to the *figure* participant shared by all extent verbs) who "measures out", or provides the scale for, the completion of the event. The verbs and *extend* and *cross* share the property of having a default motion entailment on the event readings, because their event readings entail motion along their default axes. Finally, *widen* is distinct from the others in having default reference axes, spatial axes that can be used as axes of change.

(92) The four predicates of example (1)

	Ground	motion along def. axis	def. ref. axis
widen	no	no	yes
extend	no	yes	no
cover	yes	no	no
cross	yes	yes	no

Since both *cross* and *cover* share the property of having a ground participant, I will assume they share the property of having a ground-relative scale. That is, I will assume that for *cross*, as for *cover*, the ground provides the scale, in the sense that the relevant measure function is a ratio scaled by the ground. Instead of being defined as a ratio of areas, the ratio for *cross* is a ratio of distances:

$$\begin{array}{ll} \text{cross}_{\text{S}}^{-}: & \text{I} \times \text{SI} \times \text{T} \rightarrow (0,\ 1] \\ & (x,\ y,\ [s_o,\ s_1],\ t) \mapsto \dfrac{\text{dist}^{-}(\textbf{path}_{\text{S}}^{-}(x,s_0,t),\ \textbf{path}_{\text{S}}^{-}(x,\ s_1,\ t))}{\text{dist}^{-}(\textbf{path}_{\text{S}}^{-}(x,s_0,t),\ \textbf{path}_{\text{S}}^{-}(x,\ s_1,\ t)) + \text{dist}^{-}(\textbf{path}_{\text{S}}^{-}(x,s_1,t),\ \text{END}_{\text{S}}(y))} \end{array}$$

What $\textbf{cross}_{\text{S}}^{-}$ returns is a distanceless ratio representing at time t, what fraction of the distance to the end of y x has left to travel.[26] In the picture given in Figure 5, where P_0 is the slice of the figure at s_1. The value of $\textbf{cross}_{\text{S}}^{-}$ is

$$\frac{d_0}{d_0 + d_1}.$$

A difference between the measure functions of *cross* and *cover* is that *cross* introduces an external reference point ($\text{END}_{\text{S}}(y)$, the end of the ground) which is independent of s_0 and s_1); and that the ratio computation makes reference to that reference point. Ultimately this reflects the following contrast in telicity properties between *cross* and *cover*:

(93) a. The overpass crossed the freeway from the bank to the cinema.
b. The overpass crossed the freeway.
c. The fog covered the freeway from the bank to the cinema.
d. The fog covered the freeway.

Both state functions need to be given implicit MAX values to account for the telicity of the sentences:

$$\text{cover/cross}(\sigma) = 1$$

In (a), however, the value 1 means the freeway has been entirely crossed, and (a) entails (b); in (c), 1 only means that the area between the freeway and bank is completely covered, and (c) does not entail (d).

[26]The difference between $\textbf{span}_{\text{S}}^{-}$, used in the definition of $\textbf{extend}_{\text{S}}^{-}$, and $\textbf{dist}_{\text{S}}^{-}$ is that $\textbf{span}_{\text{S}}^{-}$ is an **extent** measure (a portion of the figure must extend through the entire span of the measurement), and $\textbf{dist}_{\text{S}}^{-}$ is the distance between two poins or regions. The formulation with $\textbf{dist}_{\text{S}}^{-}$ is thus neutral between spreading motion and incremental motion.

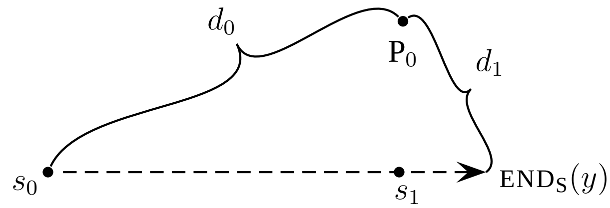

Figure 5: $\frac{d_0}{d_0+d_1}$ is the value returned by the measure function $\mathbf{cross}^{-}_{\mathrm{S}}$ for the interval $[s_0,\ s_1]$. P_0 is the slice of the figure at s_1. The dashed line is S, which coincides with the "crossing" axis of y. I.e., if y is a river, S is a line across it, perpendicular to a vertical axis.

Given that $\mathbf{cross}^{-}_{\mathrm{S}}$ is a function of spatial intervals with a ground argument, the state function definition can employ the same operator as *cover*:

$$\mathbf{cross}^{\mathrm{S}}_{\mathrm{T}}(y)(\sigma) = d \quad \text{iff} \quad \oplus^{\mathrm{S}}\boxdot^{\mathrm{T}}{}_{x,y}(\text{crossing},\ \mathbf{cross}^{-}_{\mathrm{S}})(y)(\sigma) = d$$

And event readings will require $\textsc{increase}_{\mathrm{T}}$:[27]

$$\textbf{cross-event}^{\mathrm{S,T}} = \textsc{increase}_{\mathrm{T}} \circ \mathbf{cross}^{\mathrm{S}}_{\mathrm{T}}$$

Now consider the account of extent readings for *cover*, *extend*, and *cross*. In each case we have defined a state function via a measure function defined only for spatial intervals:

(94)

State function	Measure Function
$\mathbf{extend}^{\mathrm{S}}_{\mathrm{T}}$	$\mathbf{extend}^{-}_{\mathrm{S}}(x,\ [\textsc{start}_{\mathrm{S}}(\sigma),\ \textsc{end}_{\mathrm{S}}(\sigma)], t)$
$\mathbf{cover}^{\mathrm{S}}_{\mathrm{T}}$	$\mathbf{cover}^{-}_{\mathrm{S}}(x,\ y,\ [\textsc{start}_{\mathrm{S}}(\sigma),\ \textsc{end}_{\mathrm{S}}(\sigma)], t)$
$\mathbf{cross}^{\mathrm{S}}_{\mathrm{T}}$	$\mathbf{cross}^{-}_{\mathrm{S}}(x,\ y,\ [\textsc{start}_{\mathrm{S}}(\sigma),\ \textsc{end}_{\mathrm{S}}(\sigma)], t)$

[27] Various interesting syntactic properties of the verb *cross* are being glossed over. Some of these are illustrated in (i)-(iii)

i. John crossed from the post office to the hotel.

ii. John crossed $\left\{\begin{array}{l}\text{the river.}\\ \text{the railroad tracks.}\\ \text{the street.}\end{array}\right.$

iii. John crossed $\left\{\begin{array}{l}\text{the bridge. (end-to-end reading)}\\ \text{* the tunnel.(end-to-end reading)}\end{array}\right.$

iv. The bridge/tunnel crossed the river.

In (i), the ground is left out, but there is clearly a requirement that context provide some specific entity being crossed, such as a square or a park or a street. Example (ii) gives some examples of specific grounds realized as direct objects. Note that in each of these cases the main "length" axes of the grounds are perpendicular to S, the axis of motion. Finally, (iii) illustrates the idiosyncratic properties of bridges. The main length axis of a bridge can coincide with the axis of motion; that is, the bridge version of (iii) can describe a movement from one end of the bridge to the other. Interestingly, the tunnel version of (iii), while perfectly grammatical as a description of a journey across the width of the tunnel, lacks the end-to-end reading. It seems better to describe the bridge cases as implicit grounds (the river under the bridge is the actual ground), rather than grounds with idiosyncratic axial properties, because the bridge functions as a figure in the extent readings in (iv).

Thus we define three eventuality functions homogeneous for time but not for space. We have argued that all three have analagous temporal aspectual properties, essentially that all define temporal states. Ideally all three would also have analogous spatial aspectual properties, but what we found in Section 1 was evidence that *cross* was spatially dynamic:

(95) a. The trail crossed the ridge in 20 wildly zigzagging miles.
b. Following the many bends of the river, the trail gradually crossed the valley.

No such evidence for *extend* or *cover* (at least on its default path axis). The question then: What distinguishes *cover* and *extend* from *cross*?

Note that it is not surprising that $\mathbf{cross}_{\mathrm{T}}^{\mathrm{S}}$ can directly combine with *gradually* as in (24b), even if $\textsc{increase}_{\mathrm{S}}$ is not a semantic component. It is perfectly consistent within the system outlined here to have **basic** event functions (not derived via INCREASE) along a spatial axis. The surprise, if it can be called that, is that *cover* and *extend* show no evidence of being spatially dynamic.

In what follows I will try to explain why.

Consider the case of *cover* first. Why doesn't *cover* show graduality on extent readings or evidence of being a spatial accomplishment? I want to argue that the problem is that the rate of change of the spatial eventuality function is invariant.

Consider the picture in Figure 6, which is an alternative version of the leaf-covered driveway in Figure 4. In this case, the driveway is completely covered, corresponding to an eventuality that makes the semantics for the extent reading of (96a) true:

(96) (a) The leaves covered the driveway.
(b) $\exists\sigma[\mathbf{cover}_{\mathrm{T}}^{\mathrm{S}}(\sigma) = \textsc{max} \wedge \text{figure}(\sigma){=}\text{l} \wedge \text{ground}(\sigma){=}\text{d}]$

Here MAX is a scale-relative quantity that denotes the maximum on the scale in question. In the case of $\mathbf{cover}_{\mathrm{T}}^{\mathrm{S}}$, MAX = 1. Thus this semantics asserts that the maximum possible proportion of the the driveway surface is covered by the leaves. That is, the driveway is completely covered. In general, I assume that when there is no overt degree modifier, the default value for an eventuality function is MAX, and since *cover* and *cross* never allow overt degree modifiers, the degree arguments of both are always assigned the value MAX.

Now consider the values the eventuality function takes for various sub-eventualities of σ. As we move along S, each point defines a distinct subeventuality of σ, σ', and for each such σ', either the driveway is completely covered as in Figure 6, or it simply isn't a case of covering, as in in Figure 4. That is, for each sub event of σ along S, the covering function must return a maximal value. Thus, the rate of change is constant. In fact, there is no change, so the rate of change is everywhere 0. And a property that measures 0 everywhere it's measured simply isn't a measurable property. Thus we have argued the following:

(97) When $\mathbf{cover}_{\mathrm{T}}^{\mathrm{S}}$ is maximal, the rate of change of $\mathbf{cover}_{\mathrm{T}}^{\mathrm{S}}$ is not a measurable property.

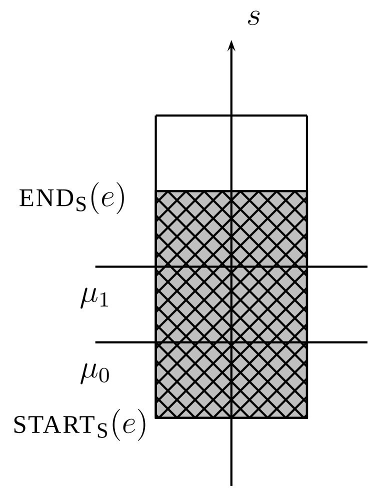

Figure 6: Leaf-covered driveway

This is already enough to explain the graduality properties of extent readings of *cover*. The adverb *gradually* is a gradable property of eventuality functions, measuring their rate of change. But eventuality functions with rates of change that are necessarily everywhere 0 are not appropriate arguments of *gradually*.

Consider in contrast the situation as the covering function $\text{INCREASE}_\text{T} \circ \textbf{cover}^\text{S}_\text{T}$ advances up the temporal axis, as in the event reading of (96a). Again we assume the eventuality function takes a maximum value:

$$\text{INCREASE}_\text{T} \circ \textbf{cover}^\text{S}_\text{T}(\sigma)(\text{d}) = \text{MAX}$$

In this case, it is not true that for each temporal subeventuality of σ, σ':

$$\text{INCREASE}_\text{T} \circ \textbf{cover}^\text{S}_\text{T}(\sigma')(\text{d}) = \text{MAX}.$$

The only requirement the semantics directly imposes is for the coverage measure to be maximal for σ. And when the axis of change is T, this can happen in many ways, quickly, or slowly, and the values of $\text{INCREASE}_\text{T} \circ \textbf{cover}^\text{S}_\text{T}$ for sub-events are unpredictable. Hence the rate of change of this eventuality function is a measurable property, and we expect graduality on the event reading.

The same is true when the spatial axis used by *cover* is a reference axis. Consider the example using the occlusion sense of *cover*, repeated here:

(98) The aneurysm grew as it approached the valve and gradually covered it.

The axis of change in this case is the line of site, and as we move along that axis the rate at which the area of the aneurysm cross-section grows is unpredictable. Therefore the rate of change is variable and graduality is possible.

Summing up, the problem diagnosed here for the spatially dynamic eventuality function is not that the $\textbf{cover}^\text{S}_\text{T}$ can't vary for sub-events (it can); nor that when it is maximal it can't vary (it can); but that when it is maximal it can't vary along the path axis S.

Something similar is true of *extend* but with qualifications. Applied to an eventuality σ, $\textbf{extend}^\text{S}_\text{T}$ returns distances. In fact, since σ starts and ends with the portion of its figure being measured, the value of $\textbf{extend}^\text{S}_\text{T}(\sigma)$, is always just the length of σ along S. Thus the rate of change of $\textbf{extend}^\text{S}_\text{T}(\sigma)$ is fixed. It can change neither gradually nor quickly. Add an inch to the "length" of σ along S and either it changes 1 inch or is undefined. There is a close analogy between *extend* and the verb *take* in its temporal sense:

(99) a. The concert took 3 hours (# in 3/6 hours).
b. # The concert gradually took 3 hours.

Viewed as eventuality function that returns durations, *take* is another fixed rate of change function, this time along the temporal axis. The length of the event being measured exactly predicts the value of take^{T} for each subevent.

The notion of an eventuality function **reaching its maximum at a fixed rate** is formalized in appendix C, along with the notion of spatial lengths of eventualities. The first requirement for a fixed rate of change is there be a MAX_{I}. MAX_{I} is the maximum value f takes for an eventuality of length I. Then f reaches its maximum at a fixed rate if and only if

> If $f(\sigma)$ is maximal for σ's length, then f is maximal for the length of any subeventualities of σ.

Thus the course of change of f is completely predictable from the length of σ. Both $\mathbf{cover}^{\text{S}}_{\text{T}}$ and $\mathbf{extend}^{\text{S}}_{\text{T}}$ reach their maxima at a fixed rate. As we move along axis S there is only one value each function can take on the path to a maximal value. The function $\mathbf{cross}^{\text{S}}_{\text{T}}$ does not maximize at a fixed rate. This is illustrated by the sentences in (95), the very same evidence used to show *cross* is spatially dynamic. A crossing eventuality can progress spatially in many ways. Thus the ratios returned for each subevent of a completed crossing event are unpredictable. Formally this is captured because the measure function underlying *cross* is computed via distances from points on the S axis, determined by the position of the figure; in terms of Figure 5, how fast crossing happens is determined by how fast d_1 shrinks, not by the size of the event. This in turn depends on the fact that d_1 is anchored to an external point which may be outside the event.

Given these observations the differences between *cross* on the one hand and *cover* and *extend* on the other can be explained as follows: The adverb *gradually* and spatial extent adverbials like *in 20 miles* both require eventuality functions that reach their maximums at variable rates. Both measure the rate of change to a maximum; and a change rate is not a measurable property if it is everywhere constant.

We can take this a step further and assert that having a variable rate of change is generally part of what we ask of Vendlerian accomplishments, and this is why the Vendlerian tests and graduality are reasonable indicators of gradable telic properties. Thus, *cross* is spatially dynamic and *cover* and *extend* are not, although all three are spatially event functions. Having a spatial event function denotation precludes being "spatially" stative like $\mathbf{wide}_{\text{S,T}}$, but it does not guarantee being dynamic. The temporal analogue for this kind of aspectual boundary case is the verb *take*, seen in (99). Clauses with *take* are neither stative nor dynamic. They are not stative since they are not homogeneous: Suppose the property of the concert taking 3 hours is true of some event e. If e even has temporal subevents, they are not 3 hour events. Nor is the property dynamic, since, as (99) shows, *take* does not pass Vendlerian test for telicity or show graduality.

The status of *cover* and *cross* then is that, like *take*, they are boundary cases; *cross* is a mainstream full-blooded spatially telic verb.

5 Change: Conclusion

It is generally recognized that spatial axes play a major role in the semantics of projective prepositions like ‘in front/back of’, ’behind’, ‘to the right/left of’, ’beside/next to’, and ’across from’. The key claim of this paper has been that there is a large class of English adjectives and verbs which also exploit spatial axes. This fact has been used to explain event/extent ambiguties for the verbs, the semantics of the relationship of degree achievement verbs to their adjectives, and various semantic details about event and extent readings, including dynamic properties of extent readings such as graduality, and fine-grained properties of the semantics of path phrases on event readings.

The technical device that connects the aspectual properties with the axial properties is called an **eventuality function**, a function from eventualities to degrees, which I have assumed to be the denotation of verbs and adjectives alike. Underlying the definition of every eventuality function is a measure function. That measure function can act as a kind of clock which counts out the portions of an event, or it can define a reference point on the measure scale at which a static eventuality can be located. In the former case, we get what I have called an event function, in the latter, a state function. For eventuality functions, the measure function is irreducibly a property of intervals, for state functions, a property of points. Thus the division between eventuality function and state function preserves one of the basic intuitions embodied in early interval semantics accounts of English tense and aspect (Bennett and Partee 1972, Dowty 1972, Taylor 1977), that “dynamic” predicates, Taylor’s *energeia* and *kinesis* predicates, need only hold at intervals, and state predicates at all points of an interval. Properties that hold only at intervals are properties that have internal structure.[28]

The key innovation here is that measure functions may be defined on both temporal and spatial axes; and thus the property of being a state function or an event function is axis relative. A two-dimensional verb denotation may be a state function along one axis and an event function along another. I have argued that this is the case for the denotations of *cover*, *extend*, and *cross*. All three have measure functions that are irreducibly properties of spatial intervals and temporally properties of moments of time. On the other hand *widen* is an event function in both dimensions; it is thus amenable to what I called the underspecification analysis in Section 1. It has a single dynamic denotation which can be evaluated along either spatial or temporal dimensions.

I have claimed that the property of dimorphism accounts for a large class of English stative verbs that are their own inchoatives, including among them the path shape verbs. All these verbs are extent predicates whose denotations are event functions on at least one axis; thus they satisfy the default pattern for English verbs of having event function denotations. Moreover, the fact that they are temporally stative means they can combine with $\textsc{increase}_T$, allowing them to be their own inchoatives. Verbs

[28]See Filip () for an excellent overview of this line of work.

exemplifying the default pattern without being two-dimensional could not combine with INCREASE_{T}. Thus the generalization is that verbs that are their own inchoatives should be extent predicates. And this appreas to be correct.

I have also argued that key semantic properties of extent predicates can be explained in terms of restrictions on axes, accounting for gaps in the distribution of the extent readings of degree achievements like *widen*, *lengthen*, and *cover*, the possibility of incremental paths, and the limited distribution of INCREASE_{S}, via a restriction I called the Independence Principle in Section 2.1. Spatial axes must be independent of the direction or plane of measurement in order for measure functions to take values at points on those axes. A consequence of this was that the spatial aspectual properties of predicates varied with axis orientation. This was the case for *widen*, *lengthen*, and *cover*, as we saw in the sentences in (28) and (30).

Finally, we looked into the question of what it meant to be spatially dynamic in Section 4. I argued that the property that distinguished the "defective" denotations of *extend* and *cover* (along its canonical axes) from that of *cross* was that *extend* and *cover* were both defined so as to have fixed rates of change. Extent readings for the verb *cross* clearly did have variable rates of change, allowing them to exhibit properties like spatial graduality. This showed that being an event function along α is a necessary but not a sufficent condition for having variable rates of change. I also suggested that variable rate of change is a necessary part of being dynamic. If this is so, and if the above account of which verbs can be their inchoatives is right, then looking at the aspectual properties of extent predicates may have given us some insight into the nature of notions like stative and dynamic, and into how they map onto syntactic categories.

Among numerous questions for future research, the most pressing seems to me: What are the ways in which spatial axes can be introduced into the semantics? Most of this paper has been concerned with lexically induced axes. I have argued that such axes are responsible for the distribution of path phrases. But we saw with *cover* that subtle shifts in meaning like the shift to the occlusion sense of *cover* can introduce new axes (30) that are independent of the axes of the path phrases (32). Also, there are clearly cases of path phrases that are not lexical. Here are two:

(100) a. From Banff on, we saw no more bald eagles.
b. Chamberlain's line advanced from the woods to the courthouse.

Example (100a) is case in which context is needed to license the path phrase. It is appropriate in a discourse in which a journey is understood to be going on. There is an axis of motion with a particular direction and that identifies what segment of trip the assertion about bald eagles should attach to. Example (100b) has a reading on which the *from the woods to the courthouse* axis is roughly perpendicular to the direction of motion and describes the extent of the troop line. This is an event reading with a verb of motion with path phrases that are clearly non-incremental. Footnote 31 discusses how to square this with the account of path phrase incrementality given in Section 3.1; the point here is that this path phrase does not seem to be lexically licensed, at least not by the verb. Rather the given axis arises because it is a salient axis of the figure (a military line), and that axis in turn licenses the path phrases. Thus both examples in (100) belong to a class of examples which suggest that the right general view of path phrases is that they are axis-licensed, not lexically licensed. Axes in turn are often, but not always, lexically licensed.

Indeed, there seems to be a large rich set of examples available in which axes of change are introduced constructionally. Thus, consider the following example from Carlson (1977):

(101) Wolves get bigger as you go north.

Treatment of such cases is beyond the scope of this paper. In particular, the use of the comparative in this case is parasitic on temporally bound comparatives such as

(102) The winters are getting colder.

That is, (101) is like (102), but with a spatial axis replacing the temporal one. Clearly the spatial axis in (101) is licensed not by any part of the clause *wolves get bigger*, but by the movement described in *as you go north*.

Contextually and constructionally introduced axes have been given short shrift here, but they appear to offer fertile ground for much future work.

Appendices

Appendix A: From measure functions to state functions

In alternative (a), criterion (ii) guarantees what Krifka (1989)a calls **Homogeneity** along the L axis, following up on the notion of homogeneity raised in Vendler (1957).[29] Homogeneity has two components. The first is called **Divisiveness**. Suppose

$$\boxdot^{\mathrm{S,\,T}}{}_{x}(\mathrm{C},\ f_{\mathrm{L}})(\sigma) = d.$$

Applying criterion (a[ii]) in the rightward direction, we have:

$$\forall i \in \mathrm{L}_{\sigma}\ f(\theta_{\mathrm{C}}(\sigma))(i) = d$$

Any C-substate σ' of σ such that

$$\begin{array}{l} \theta_{\mathrm{C}}(\sigma) = \theta_{\mathrm{C}}(\sigma') \quad \text{and} \\ \mathrm{L}_{\sigma'} \sqsubseteq \mathrm{L}_{\sigma} \end{array}$$

must therefore, applying criterion (a[ii]) in the leftward direction, be such that

$$\boxdot^{\mathrm{S,\,T}}{}_{x}(\mathrm{C},\ f_{\mathrm{L}})(\sigma') = d.$$

The other half of Homogeneity is called **Cumulativity**. Suppose we have three C-states σ, σ' and σ'' such that:

$$\begin{array}{l} \theta_{\mathrm{C}}(\sigma) = \theta_{\mathrm{C}}(\sigma') = \theta_{\mathrm{C}}(\sigma'') \quad \text{and} \\ \mathrm{L}_{\sigma'} \cup \mathrm{L}_{\sigma''} = \mathrm{L}_{\sigma} \end{array}$$

[29]The following discussion oversimplifies matters in at least one important respect. In order to derive cumulativity and divisiveness from (a[ii]) we need to assume that the basic classifying predicate C is divisive and cumulative.

and suppose

$$\boxdot^{\text{S, T}}{}_x(\text{C},\ f_{\text{L}})(\sigma') = d \quad \text{and}$$
$$\boxdot^{\text{S, T}}{}_x(\text{C},\ f_{\text{L}})(\sigma'') = d$$

Then, applying criterion (a[ii]) in the rightward direction we have:

$$\forall i \in \alpha_{\ \sigma'} \cup \alpha_{\ \sigma''}\ f(\theta_{\text{C}}(\sigma))(i) = d$$

And therefore, applying criterion (a[ii]) in the leftward direction, we have:

$$\boxdot^{\text{S, T}}{}_x(\text{C},\ f_{\alpha}\ )(\sigma) = d.$$

The formal axiomatic definitions of Cumulativity and Divisiveness for state functions are given at the end of this section. The definitions differ from those in Krifka (1989)a in that Krifka is not concerned with the case of measure functions, but these seem to be the natural specializations for the special case of a state which maps a figure-property to some point on a scale. The key innovations in the present context are explicit mentions of the value of the state function and of the axis of change. Accordingly, the notion of sub-state that is relevant is $\sqsubseteq_{\alpha}$ (**substate along L**):

$$\sigma' \sqsubseteq_{\alpha}\ \sigma \text{ iff } \alpha_{\ \sigma'} \subseteq \alpha_{\ \sigma},$$

where $\alpha_{\ \sigma}$ is the set of L-axis coordinates of σ.

What does homogeneity mean? If L = T and a measure, say width, is changing in time, σ has be short enough in duration for $wide(\sigma)$ to take a well-defined constant value; if the width of the figure is constant over an extended period of time, the temporal trace of σ may extend over that entire duration. In general, as noted by Krifka, homogeneity neither forces states to be instantaneous nor extended. All divisiveness says is that *if* σ has subparts, the value for the measure function is the same for those subparts as it is for σ; all cumulativity says is that if two C-states whose measure function takes value d are combined into a larger C-state, that larger state takes value d for the measure-function.

Although cumulativity is discussed in Gawron (2005), Krifkean homogeneity is not enforced and alternative (b) is taken. One could impose homogeneity on alternative (b) by simply adding the following:

$$\forall i \in \alpha_{\ \sigma}\ f(\theta_{\text{C}}(\sigma))(i) = d$$

However this would be a peculiar choice from the point of view of theory design. Since the state σ now completely determines the value d, this makes the i in:

$$\boxdot^{\text{S, T}}{}_x(\text{C},\ f_{\alpha}\ )(\sigma)(i) = d$$

completely superfluous.

Therefore, since I wish to adopt homogeneity, I have also, contra Gawron (2005), adopted alternative (a).

The original Krifkean definitions of divisiveness and cumulativity follow:

Divisiveness $\textsc{div}(\textsc{p}) \leftrightarrow \forall x, y[\textsc{p}(x) \wedge y \leq x \rightarrow \textsc{p}(y)]$
Cumulativity $\textsc{cum}(\textsc{p}) \leftrightarrow \forall x, y[\textsc{p}(x) \wedge \textsc{p}(y) \rightarrow$
$\textsc{p}(x \oplus y) \wedge \exists x, y[\textsc{p}(x) \wedge \textsc{p}(y) \wedge x \neq y]\,]$

Building on Krifka as well as on Zwarts (2005), Gawron (2005) defines the notion of Axial Cumulativity

(103) A property P is cumulative with respect to axis L iff

$$\forall e_1,\, e_2 \quad [\mathrm{P}(e_1) \wedge \mathrm{P}(e_2) \wedge \exists\, \pi\, \mathbf{path}_{\,\mathrm{L}}(e_1 \oplus e_2) = \pi\,] \rightarrow \mathrm{P}(e_1 \oplus e_2)$$

The definition of axial cumulativity says that a property P is cumulative with respect to axis L iff when you sum two P-events and a path exists on axis L for that sum, then P holds of of the sum.

This kind of cumulativity is actually **stronger** than what is needed here. Hence, in the interest of finding a satisfactory acount with the weakest possible assumptions, I propose replacing the above definition of axial cumulativity with the following definition, which does not rest on the assumption of paths:

Axial Cumulativity(Weaker version)
$\forall e_1,\, e_2[\mathrm{P}_{\mathrm{L}}(e_1) \wedge \mathrm{P}_{\mathrm{L}}(e_2) \wedge \alpha_{\,e_1} \cup \alpha_{\,e_2} = \alpha_{\,e_1 \oplus e_2} \rightarrow \mathrm{P}_{\mathrm{L}}(e_1 \oplus e_2)]$

This version of axial cumulativity is entailed by the path-based version, but does not entail the path-version.

Appendix B: Definitions of path operators

The definitions in (104) show one route for defining the location function (c) and path operators (d and e) used in this paper.

(104)

	Term	Definition
(a)	$\textsc{at}(x, t) = l$	l is the location of x at time t
(b)	$\textsc{at}^{\mathrm{S}}(x, s, t) = l$	$\textsc{at}(x, t) \sqcap \text{plane}(s, \mathrm{S}) = l$
(c)	$\text{path}^{-}_{\mathrm{S}}(x,\ [s_0,\ s_1],\ [t_0,\ t_1]\ ) = l$	$\bigsqcup_{\substack{s_0 \leq s \leq s_1 \\ t_0 \leq t \leq t_1}} \textsc{at}^{\mathrm{S}}(x, s, t) = l$
(d)	$\mathbf{path}^{\mathrm{S}}_{\mathrm{T}}(e)(t) = l$	$\text{path}^{-}\begin{pmatrix} \text{figure}(e), \\ [\textsc{start}_{\mathrm{S}}(e), \\ \textsc{end}_{\mathrm{S}}(e)], \\ t \end{pmatrix} = l$
(e)	$\mathbf{path}_{\mathrm{S}}(e)(s) = l$	$\forall t \in [\textsc{start}_{\mathrm{T}}(e),\ \textsc{end}_{\mathrm{T}}(e)]$ $\text{path}^{-}\begin{pmatrix} \text{figure}(e), \\ s, \\ t \end{pmatrix} = l$

All of the terms defined in (104) denote locations (either points or regions). Definition (104a) introduces a basic universal location function, AT, which returns the location of any x at time t; while (b) introduces a slicing version of that function:

$$\text{AT}^{\text{S}}(x, s, t)$$

returns the portion x intersected at time t by some plane perpendicular to axis S at index s.[30] The function introduced in (c) is the location function underlying both path operators; the relation it bears to those operators is analagous to that born by measure functions to state or event functions; it returns the eventuality-independent "measure" of a property and has therefore been superscripted with the same superscript^{-} distinguishing the other eventuality-independent functions. It is also distinguished by being defined for spatial and temporal intervals. Hence, it can return the entire location "trace" of x over some spatial and temporal interval. This will come in handy, for example, in defining the semantics of path-shape verbs like *zigzag*; a zigzagging motion will be one whose path^{-} trace is zigzag-shaped; but so will a zigzag-shaped figure. As a degenerate case path^{-} is defined for points on S and T as well, writing s as

$$[s,\ s]$$

Definition (d) makes $\mathbf{path}_{\text{T}}^{\text{S}}$ a function from events to to functions from time instants to locations of the figure. Those locations are constrained to fall within the bounds of e as given by axis S, but since $\mathbf{path}_{\text{T}}^{\text{S}}$ is mainly of service in motion predicates and since S is usually aligned with the direction of motion, S is usually omitted from $\mathbf{path}_{\text{T}}$. Definition (e) makes $\mathbf{path}_{\text{S}}$ a function from eventualities to functions from spatial indices to locations. This time there is a universal quantification over times, meaning each slice of the figure has to be in the same location for the entire duration of e;[31] $\mathbf{path}_{\text{T}}^{\text{S}}$ and $\mathbf{path}_{\text{S}}$ return different kinds of things; $\mathbf{path}_{\text{T}}$ will generally return the location of the entire figure at a time, while $\mathbf{path}_{\text{S}}$ will return the location of a slice of the figure at index s.

Lines (d) and (e) of (104) are not intended as definitions. They are rightward

[30]We assume the existence of an empty location, written λ, as the value returned by $\text{AT}^{\text{S}}(x, s, t)$, when the intersection of the s-plane with x's location is empty. λ is a lower bound for every location, so for any location l:

$$\lambda \sqcup l = l.$$

[31] Example (100) seems to be a case in which the axis of the path phrases are not aligned with the direction of motion.

(i) Chamberlain's line advanced from the woods to the courthouse.

This has a reading on which the *from the woods to the courthouse* axis is roughly perpendicular to the direction of motion and describes the extent of the troop line. Since on this reading the path phrase is clearly non-incremental, and motion is clearly entailed, this kind of an example is on the face of it a problem for (104); neither kind of path fits. What seems to be going on here is that the figure has a salient axis of its own which is being exploited by the path phrase. Moreover since the axis is an intrinsic axis of the figure, the frame of reference moves with the figure. Therefore, there is no motion relative to that axis and the homogeneity condition in (104e) still holds.

implications. The real definitions are as follows:

$$\textbf{path}^{\mathrm{S}}_{\mathrm{T}}(e)(t) = l \text{ iff path}^{-}\begin{pmatrix}\text{figure}(e),\\ [\textsc{start}_{\mathrm{S}}(e),\\ \ \textsc{end}_{\mathrm{S}}(e)],\\ t\end{pmatrix} = l \wedge \exists d\, \mathcal{F}^{\,\mathrm{S}}_{\,\mathrm{T}}(e) = d$$

$$\textbf{path}_{\mathrm{S}}(e)(s) = l \text{ iff } \forall t \in [\textsc{start}_{\mathrm{T}}(e),\ \textsc{end}_{\mathrm{T}}(e)]$$
$$\text{path}^{-}\begin{pmatrix}\text{figure}(e),\\ s,\\ t\end{pmatrix} = l \wedge \exists d\, \mathcal{F}_{\mathrm{S}}(e) = d$$

Here $\mathcal{F}_{\mathrm{S}}$ and $\mathcal{F}^{\mathrm{S}}_{\mathrm{T}}$ represent some axial eventuality function. That is, path operators of both kinds are defined only when axiality eventuality functions are defined.

This means:

(105) All axial predicates have $\textbf{path}_{\mathrm{S}}$ and $\textbf{path}_{\mathrm{T}}$ in their signature.

Appendix C: Eventuality Length

In this section I assemble a few notes on how to generalize the notion of length to eventualities defined for spatial axes.

As defined thus far, axes are just sets of points, so the idea of interval lengths on axes does not quite come for free, but it almost does if we assume some primitive distance function for pairs of points in space. The preliminary step is to assign real numbers to points on all axes in some way that respects a standardized notion of length. The notion required here is a uniform **length scaling** of all axes.

A scaling L is an assignment of real numbers to the points on all axes. I write L(S)(s) for the real number assigned to the index s on axis S by L. L is a **length scaling** of all axes if and only if for all axes, S, S', all indices of S, s_1, s_2, and all indices of S', s_3, s_4,

$$\boxed{\mathrm{L(S)(s_2)} - \mathrm{L(S)(s_1)} = \mathrm{L(S')(s_4)} - \mathrm{L(S')(s_3)}}$$

if and only if the spatial interval $[s_1,\ s_2]$ on S and the spatial interval $[s_3,\ s_4]$ on S' are of equal length.

Given such an L, I will generally just write $s_2 - s_1$ to refer to the length of the interval $[s_1,\ s_2]$.[32] And since I am interested in sets of eventualities of equal length, I will define Σ_{I} for the set of eventualities of interval length I

$$\Sigma_{\mathrm{I}} = \{\sigma \mid \exists \mathrm{S}\textsc{end}_{\mathrm{S}} - \textsc{start}_{\mathrm{S}} = \mathrm{I}\}$$

I define $\textsc{max}_{f,\mathrm{I}}$, the $\textsc{max}$ value of function f for interval I as follows:

$$\textsc{max}_{f,\mathrm{I}} = \max_{\sigma \in \Sigma_{\mathrm{I}}} f(\sigma)$$

[32] That is, $s_2 - s_1$ is an abbreviation for $\mathrm{L(S)}(s_2) - \mathrm{L(S)}(s_1)$.

Where f is clear, I write simply $\textsc{max}_{\mathrm{I}}$.

We now define the notion of **reaching a maximum at a fixed rate**.

An eventuality function f reaches its maximum at a fixed rate if and only if

$$\begin{aligned}\forall\sigma,\sigma'[\ &[f_{\mathrm{S}}(\sigma) = \textsc{max}_{\mathrm{I}} \wedge \mathrm{I} = \textsc{end}_{\mathrm{S}}(\sigma) - \textsc{start}_{\mathrm{S}}(\sigma) \wedge \sigma' \sqsubseteq_{\mathrm{S}} \sigma]\mathrm{I'} = \textsc{end}_{\mathrm{S}}(\sigma') - \textsc{start}_{\mathrm{S}}(\sigma')] \\ &\rightarrow \\ &\wedge f_{\mathrm{S}}(\sigma') = \textsc{max}_{\mathrm{I'}}]\end{aligned}$$

That is, if $f(\sigma)$ is maximal for σ's length, then f is maximal for the length of any subeventualities of σ.

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