Generalized Paths

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1 Introduction

What is change? Specifically, what lexical properties make sentences describing Vendlerian events (Vendler 1957), different from sentences describing Vendlerian states? In this paper I want to discuss a class of spatial predicates that have both state and event readings whose properties illuminate the paired semantic concepts of state and event. I will show that the state readings for these sentences illustrate a special class of states compatible with change and I will argue that the key lexical property licensing such *dynamic states* is the presence of a path component in the semantics. The key feature that links path with change is that a path provides an axis other than time with respect to which change can be measured.

The facts at issue involve a class of predicates discussed by a number of authors (Anderson 1977, Jackendoff 1990, 1996, Matsumoto 1996, Talmy 1996). Consider the sentences in (1):

(1) a. The fog extended from London toward Paris. (Jackendoff 1990)
b. Debris covered the outfield.
c. Water filled the glass.

Sentence (1a) has two readings, one which I'll call an event reading, on which a body of fog beginning in the vicinity of London moves Pariswards, and another I'll call an *extent* reading, on which a mass of fog sits over the entire region between London and Paris. The event reading entails movement. The extent reading entails extension, the occupation of a region of space. (1b) and (1c) exhibit similar ambiguity: The debris comes to cover the outfield (event), or litters its surface (extent); the water in (c) moves into the glass (event), or may simply be at rest, occupying its interior.

In certain cases it's easy to disambiguate event and extent readings with adverbial modifiers, as in (2); (2a) only has the event reading; (2b) only the extent reading.

(2) a. Fog *gradually* covered the city. (event reading only)
b. Fog covered the city *for 3 hours*. (extent reading only)

I will use the term extent predicate for any predicate that has extent readings. Examples are *clutter*, *cover*, *dot*, *envelope*, *extend*, *fill*, *span*, and *surround*. I will also use the term *figure* for the participant extended in space, the fog in (2a), and the term *ground* for a second participant generally in some close spatial relation with the figure throughout its extent, the city in (2a).

1.1. Basic Properties

A basic descriptive generalization about extent predicates, regarded as criterial by Jackendoff (1990), is that they allow path phrases determining the space the figure occupies:[1]

(3) a. Snow covered the mountain from the valley floor to the ridge.
b. Snow covered the mountain.

Note that these path phrases do not follow the typical entailment pattern of a path phrase, or, indeed, an optional oblique. Sentence (3a) does not entail (3b): (3a) asserts that the portion of the mountain specified by the path was covered; (3b) asserts that the entire mountain was covered (or at least that the entire visible surface of the mountain is covered). Apparently, there is a default value for the region argument (in the case of *cover*, the entire surface of the ground). I take the existence of a default path value delimited by the ground argument as evidence that path is an argument for extent predicates.

A significant wrinkle is that a large class of extent predicates shows distinct selection restrictions for event and extent readings. Example (4) shows some cases drawn from the *path-shape* verbs of FrameNet (Fillmore and Baker 2000).

(4) a. The road zigzagged up the hill. (extent reading only)
b. The halfback zigzagged toward the goal line. (event reading only)

(5) shows a list of other path shape verbs showing the same figure selection pattern:

(5) 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

Although it appears at first as if the change in selection restrictions must be handled by some sense transfer rule, I would argue that a single sense applies in both event and extent readings. The semantic constancy of path-shape verbs is captured by the class-name: in both event and extent uses each path shape 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*. The figure in an extent reading is always represented as *extended* over the entire path, and the property being attributed is always a spatial configuration of the figure's parts. It follows that figures that cannot be extended in the required configuration (such as halfbacks) are disallowed.

The remaining question is why verbs like *zigzag* allow non-extended figures like halfbacks on their event readings while verbs like *extend* do not. It is an idiosyncratic property of verbs like *extend* and *surround* that they describe 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 contrast, path-shape verbs like most motion verbs can depict *displacement*, advancement to a new location accompanied by removal from an old one, allowing rigid figures like halfbacks.

In sum, extended figures are always required on extent readings, but only sometimes required on event readings. Thus, the change in selection restrictions between event and extent readings for path-shape verbs is due not to any particular feature of the event/extent alternation, but to the fact that constraints on displacement differ from those on spreading motion. If we can show that the event/extent alternation can be handled without a change of sense, we can account for the path-shape verbs without a change of sense.

Thus far we have examined a class of interesting but essentially unproblematic stative readings. We turn now to a class of extent predicates for which I will argue that we have state readings predicating change. Consider (6):

(6) a. The crack widened at the north gate.
b. The crack widened from the tower to the north gate.
c. narrow, warm, cool, rise, fall, darken, lengthen, lighten, brighten, dim, grow color adjectives

Sentence (6a) has both state and event readings. On the event reading the crack is wider at certain moment in time than it was just before that. On the state reading (which I will also call an extent reading), the crack is wider at the north gate than it is elsewhere. Sentence (6b) shows that, like the extent predicates we have seen before, *widen* takes path arguments (and the ambiguity persists). Sentence (6c) lists other degree achievement verbs that exhibit extent/event readings.

At first blush it might appear that *lengthen*, in contrast to *widen*, does not allow extent readings, on the basis of contrasts like the following:

(7) a. The cable widened in the den.
b. The cable lengthened in the den.

Sentence (7a) has an extent reading: "The portion of the cable in the den was wider than elsewhere.' In contrast, though (7b) has a perfectly good though unlikely event reading, it has no extent reading. It cannot mean: "The portion of the cable in the den was longer than elsewhere."

But examples with *lengthen* are possible if the correct choice of *figure* is made, that is, if we are looking at the kind of object whose length can vary along the axis implied by the path phrase:[2]

(8) The dress lengthened in back.

In fact the contrast between cables and dresses and how their lengths are measured provides an important clue as to how extent readings with scalar predicates work. Example (8) works because the path phrase *in back* defines a front to back axis along which the lengths of successive axial sections of the dress increase. The only axis available for (7) is an axis that defines successive cross sections of the cable, and the contrast between (7a) and (7b) is due to the fact that cable cross-sections conventionally have widths but not lengths. This example provides the key concept connecting extent readings and paths: the idea of an axis. Extent readings assert properties extended along a spatial axis, describable by a path. We will return to this point in section 5.

Examples (6), (7), and (8) show that extent readings with *widen* and *lengthen* describe a change in measurement. Thus, the extent reading of (6a) claims that at some point in space the crack is wider than it was at an "earlier" point. Consistent with the notion that change is really involved, adverbials of change are possible:

(9) The crack gradually widened from the north gate on.

In (9) the extent reading is perfectly possible; as we move through space, the width of the crack **slowly** increases. I take this as another diagnostic of change.

The clinching argument that extent readings with *widen* describe change is that they pass Vendlerian tests for being accomplishments and achievements, if the frame adverbials used employ spatial intervals:

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

Example (10a) shows that extent-*widen* occurs in descriptions of spatial accomplishments; and example (10b) shows that it also occurs in in spatial activities. I take these, as Vendler does, as behaviors diagnostic of verbs of progression and change.

This might lead one to believe that they cannot therefore be statives. But extent readings share an important semantic property with statives:

(11) a. # The crack was being an inch wide.
b. # The crack was widening an inch from the north gate on.(extent reading)
c. # The fog was extending from London to Paris. (extent reading, cf. 1a)

Example (11a) shows the classic incompatibility of statives and the progressive; (11b), the degree achievement version, has the temporal reading of a crack slowly widening in time, but it can't mean the crack was wider at the north gate than elsewhere. Example (11c) shows that the extent reading is also missing for a progressive version of (1a). Thus extent readings are incompatible with the progressive. Incompatibility with the progressive is a standard diagnostic for statives (Dowty 1979); I thus conclude that extent readings can simultaneously be stative and describe change.

Talmy (1996) describes a number of examples superficially similar to those we have been discussing as cases of "fictive motion". An objection to applying this description here is that it obscures natural constraints on the construction.

If (1a) “imagines” a fictional journey over the course of the valley, why can’t the description of that fictional journey be put in the progressive? In fact it appears these examples can be distinguished from a class of the cases Talmy discusses which do allow the progressive:[3]

(12) a. The scenery was rushing past me.
b. The road was widening.

Both examples can be used to describe objects (scenery in (a), the road in (b)) that are in fact unchanging with respect to time. On that reading, however, both require that the speaker be moving with respect to the objects. I submit that that these are the true fictive motion cases and that, relative to the right frame of reference, both (12a) and (12b) are examples of event readings: At successive moments of time the location of the scenery with respect to the speaker changes; at successive moments of time, the road’s width measurement at a fixed point in the speaker’s frame of reference increases. That is, both situations involve change with respect to time. Since the key requirement for using the progressive is change with respect to time, these readings are distinguished by the grammar from extent readings, in which there is no change in time relative to any frame of reference.

In sum, all extent readings, even those that describe change with respect to space, are stative in the sense that they describe situations static with respect to time and, consistent with that, they are incompatible with the progressive. In contrast, genuine fictive motion examples clearly involve change with respect to time and, consistent with that, they are compatible with the progressive.

This leaves a cluster of properties to be explained:

(13) a. What semantic property characterizes extent predicates? Why are figures required to be extended in space?
b. Why does this phenomenon correlate with path modifiers?
c. These are statives. How do statives preserve aspectual properties? In particular, how can we account for the spatial activity and accomplishment properties exemplified in (10)?

In the remainder of this paper, I will attempt to answer these questions and, in so doing, I will formalize the notion of change with respect to space. The key idea is that these readings exploit contextually determined spatial axes independently motivated in the language of space, using them as axes along which to measure change. The accessibility of such axes will in turn require a predicate with path as a semantic component. Using the example of degree achievement verbs and verbs of motion, I will show how the 3 properties in (13) are accounted for: how both accounts incorporate the semantics of paths, how this leads naturally to an account of the aspectual properties of extent readings, and how extent predicates can be semantically characterized. I will also propose a treatment able to account for event/extent ambiguities without a change of sense.

2 Spatial Axes as Dimensions for Change

I argue that the first assumption required in order to account for change with respect to space is that of a *spatial axis*, an ordered set of collinear points that can serve as an *axis of change*, and I argue further that axes that are independently motivated for the language of space 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 (14)

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

The point of this example is that it describes a change that is independent of time: a functional dependence between altitude and boiling point. Informally: 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 (15):

(15) a. **An axis** is a set of elements with a well-ordering.
b. The Fahrenheit scale is an axis, and in (14) 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 (6a) and (6b).

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. Consider (16a) and (16b). Following Fong (1997), I will call these *diphasic locatives*.

(16) 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 (16a) 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. Call this the *axis of reference*. The second point is that the directionality of Fong's axis interacts directly with extent readings. Sentence (16c) 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; (16d) 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 axes of reference in (16a) and (16b) are identified with the axes of change.

Contextually imposed axes arises more famously in spatial language in the case of projective prepositions such as *behind*, *in front of, in back of, above, below, beside*, and *ahead of*:

(17) a. The futon is behind/beside the chair.
b. The futon is behind the boulder.
c. The dress lengthens in back.

In (17a) 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 axis of reference, in which the ground has a canonical orientation that determines the direction of the axis, *intrinsic*, following Fillmore (1971), Tversky (1996). In (17b), 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 (16) is that directionality is involved, and this directionality seems to be describable via an axis that goes through the ground, Ukiah in (16), the chair and boulder in (17). (17c), 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 is from the dress's front toward its back, that is, the same direction as its intrinsic front-to-back axis. Again, the axis of reference is identified with the axis of change.

Summing up: Examples (16) and (17) make two points, first, that the idea of ordered collinear sets of spatial points, the idea of axes, is independently motivated within the language of space, and thus the existence of linguistic phenomena using spatial axes as axes of change is natural;[4] second, that the axis of reference and the axis of change are very naturally identified.

I assume provisionally that the axis of reference always goes through the ground, whether intrinsic or extrinsic. The primary function of an axis of reference is to locate and orient other objects with respect to the ground; when the occasion arises, the axis of reference can also function as an axis of change.

I will assume that time, too, is an axis, the axis, that, in the usual case, is used for tracking change. I use L for unambiguously spatial axes, T for the temporal axis, and S for an axis that may be either:

(18) a. *Let L be a spatial axis.* Choose a frame of reference that makes L the x-axis. L is thus represented as a set of coordinates of the form $\langle x, 0, 0, 0 \rangle$, where the last coordinate is time.

b. *Let T be the time axis.*

c. Tplane$(s,\ \mathrm{S})$ is the set of points that project on to point s on axis S. For the time axis T, Tplane$(t,\ \mathrm{T})$ is just the set of spatiotemporal points that are *at* time t. For a spatial axis L Tplane$(s,\ \mathrm{L})$ is a plane projected along the time axis, a spatiotemporal region which, at each moment of time, picks out the same plane.

We will locate an entity on an axis by means of a function called SLICE.

(19) *Slices of an entity at an index*

The slice of entity x at index s is the intersection of the the spatiotemporal trace of entity x (the spatiotemporal "worm" giving individual x's location at each moment in time) with the T-plane at s:

$$\mathrm{slice}_{\mathrm{S}}(x, s) = \mathcal{T}(x) \sqcap \mathrm{Tplane}(s, \mathrm{S})$$

When s is spatial, slice gives us the cross-sections of x at s, one for each time x crosses s; when s is temporal it gives us the temporal stage of x at t. The asymmetry is due to the fact that an individual can be in only one place at time t, but can return to the same place many times.

Slice is thus a kind of Laplacean Demon function. It gives the location of everything relative to every axis. In section 4, the notion *path* is defined as a relativization of slice to events: a general function for locating the figure participant of an event relative to an axis.

3 Degree Achievements

I begin with an analysis of *widen* because this is the most intuitive case among the extent predicates. In this section, I show how the idea of a spatial axis along which we can slice cross-sections of an entity provides us with an account of the extent readings of *widen*.

I will start by summarizing the analysis of Hay et al. (1999), henceforth HKL, which will require only a minor change to handle extent readings.

For HKL, an adjective like *wide* denotes a function from entities and times to degrees. Looking ahead to the treatment of path phrases we introduce events for the adjective: (a) and (b) are truth-conditionally equivalent:

a. $\mathrm{width}_{\mathrm{L}}(x)(t) = d$

b. $\exists\sigma[\mathrm{figure}(\sigma){=}x \wedge \mathrm{wide}_{L}(\sigma)(t) = d\,]$

While remaining remaining neutral on whether a type or sort distinction needs to be made, we will informally mark the distinction between width states and widening events by using e for events and σ for states. Here L is the axis of reference, perpendicular to which widths are measured,[5] x is the measured object, which we refer to as the figure, and d is a degree of width.

The semantics of the verb *widen* is derived by combining the *wide* function with an *increase* operator, which introduces a difference argument. Schematically:

$$\text{widen by d -much iff increase(wide)}_{\text{S}}(e){=}d$$

d is the *increase* argument, measuring the amount of change in e on the adjectival scale.

With adjectival events, the *increase* operator is defined as follows:

(20) $$\forall t_1,\, t_2,\, x,\, d \left[\begin{array}{l} \exists e\,[\ \text{increase}(\text{wide}_{\text{L}})(e) = d \wedge \\ \qquad \textsc{start}(e){=}t_1\ \wedge \textsc{end}(e){=}t_2\ \wedge \text{figure}(e){=}x\,] \\ \qquad\qquad\qquad \longleftrightarrow \\ \exists \sigma_1,\, \sigma_2[\ \textsc{start}(\sigma_1){=}t_1\ \wedge \textsc{end}(\sigma_2){=}t_2 \wedge \\ \qquad\quad \text{figure}(\sigma_1) = \text{figure}(\sigma_2) = x \wedge \\ \qquad\quad \text{wide}_{\text{L}}(\sigma_1)(t_2) = \text{wide}_{\text{L}}(\sigma_2)(t_1) + d\,] \end{array}\right.$$

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

$$\text{increase}(\text{wide}_{\text{L}})(e) = d$$

The revision required to admit extent readings is quite simple: Make *increase*, START, and END all sensitive to what axis change is being measured on. Using S for the axis of change, whether temporal or spatial, and $s_1,\ s_2$ for indices on the axis, we would substitute the following into (20):

$$\begin{array}{c} \ldots \text{increase}_{\text{S}}(\text{wide}_{\text{L}})(e) = d \ldots \\ \ldots \textsc{start}_{\text{S}}(e){=}s_1\ \wedge \textsc{end}_{\text{S}}(e){=}s_2\ \ldots \\ \longleftrightarrow \\ \ldots \textsc{start}_{\text{S}}(\sigma_1){=}s_1\ \wedge \textsc{end}_{\text{S}}(\sigma_2){=}s_2\ \ldots \end{array}$$

When S is spatial it must be a contextually supplied axis, and the most salient one is L, each index of which determines a cross-section of the figure with a (potentially different) width. When S is temporal, we simply have the case of (20) again.

The definition of the START of an event with respect to an axis is:[6]

(21) $$\textsc{start}_{\text{S}}(e) \;=\; \underset{p \in \mathcal{T}(e)}{\text{Min}}\ \text{coordinate}(S,\, p)$$

The start and end of e along axis S are the respective minima and maxima of the projection of e's spatiotemporal trace onto S. An event will thus have different starts and ends, depending on what axis is used.

We have now said enough to address a simple case:

(22) a. The crack$_c$ widened half an inch.

b. $\exists e$ [increase$_{\mathrm{L}}$(wide$_{\mathrm{L}}$)(e)=[.5 in] $\wedge$ figure(e)=c]

The extent reading of (22a) is represented in (22b), as the choice of L, the axis of reference for width measurement, as the axis of change for *increase*. According to our revised version of (20), this is true if and only if the difference in the value of the width function between the start and end of e as measured along axis L is .5 inch.

Note that this analysis makes no use of an aspect-changing operator, such as the inchoative operator used in the analysis of extent predicates in Jackendoff (1990). Essentially the same meaning is claimed to yield both readings, the difference lying in which axis is used for the evaluation of change. This makes the prediction that the extent readings and event readings for *widen* have essentially identical aspectual properties.

This appears to be correct. On event readings, *widen* falls into a sizable class of degree-achievement verbs that can be both activities and accomplishments, depending on the exact width property at issue. Example (23) illustrates this.

(23) a. The crack widened five inches in five minutes.

b. The crack widened for several hours.

Thus, the extent readings for *widen* in (10) preserve exactly the aspectual properties of the event readings.

This is the basic idea. Some major issues remain. Consider (24):

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

A complete account should also explain why and how path expressions like those in (24) enter into the truth conditions of *widen*. It should also work for extent predicates. The next two sections address these questions.

4 Analysis of Motion Predicates

Our next task is to extend the idea of change with respect to space into the semantic domain of motion and extent predicates like the path-shape verbs and *extend*. The analysis of change in width events employed a width function, a function tracking change in widths. We will use the term *path function* for the analogous concept in the domain of motion and extent: a path function is a function tracking change for motion and extent predicates. In this domain, the change to be tracked is change in location; thus the range of a path function is not a *scale* (an ordered set with additions and differences) but simply locations.

4.1. Path

We begin by defining an operator we call **path** which, for each appropriate event, will return the change function that tracks the location of the event's *figure* (or theme) with respect to either space or time. The **path** operator, then, returns a function for each event (exactly parallel to the *wide* operator used for the adjective *wide*). The function returned (which we will denote by π) will be called the path of the event.[7]

A path function π is just some subfunction of slice with restrictions limiting it to one event. The idea is spelled out in (25a).

(25) $\textbf{path}_{\mathrm{S}}(e){=}\pi$ iff $\pi : [\textsc{start}_{\mathrm{S}}(e),\ \textsc{end}_{\mathrm{S}}(e)] \rightarrow$ Locations and
$\pi : \mathrm{s} \mapsto \mathrm{slice}(\mathrm{figure}(e),\ s) \sqcap \mathcal{T}(e)$
Restriction: if $l \in \mathrm{Range}(\pi)$ then l is a connected region.[8]

The path π of an event e is a function from a spatial or temporal index s to the location of e's figure at s. Note that the domain of π is defined by the axis S and that π is restricted to the interval of S in e. This, again, is done by means of START and END of e points along S. Thus, there are many path functions for any given event, corresponding to the starts and ends determined by each axis through it.

The key property of a path for our purposes is that it is always defined relative to an axis. When s is a point s_0 on spatial axis L, $\textbf{path}_{\mathrm{L}}(e)(s_0)$ is a slice of the figure of e defined over the time interval for which e is defined. When s is a time t_0, $\textbf{path}_{\mathrm{T}}(e)(t_0)$ is the location of the figure at time t_0.

Two consequences of this definition are worthy of special note. First, when paths are defined with respect to spatial indices, there is no motion entailed. What changes from index to index with a spatially indexed path is the parts of the figure being located. As I will illustrate in the next section, this *generalized notion of path* will yield both extent and event readings for motion predicates. The unifying idea is not motion but an axis along which location is tracked.

The second point is that paths are event-relative; they are defined to respect the boundaries of their events. This feature invites the definition of a path-determined (and therefore axis-determined) ordering on events:

(26) $e_1 \sqsubseteq_{\mathrm{S}} e_2$ iff $\textbf{path}_{\mathrm{S}}(e_1) \subseteq \textbf{path}_{\mathrm{S}}(e_2) \wedge e_1 \sqsubseteq e_2$

Read $e_1 \sqsubseteq_{\mathrm{S}} e_2$ as e_1 is a subpart of e_2 along axis S. Here $\subseteq$, which means "subpath of", is just the natural ordering on functions:

$$f_1 \subseteq f_2 \text{ iff } \mathrm{Dom}(f_1) \subseteq \mathrm{Dom}(f_2) \quad \text{and} \quad \forall x, y\, [\, \langle x,\, y \rangle \in f_1 \rightarrow \langle x,\, y \rangle \in f_2]$$

An event e_1 is a subpart of an event e_2 along axis S if and only it is a subpart of e_2 and the path of e_1 along axis S is a subpath of the path of event e_2. This will entail that both events have a figure, that the figures of the two events are the same, and that the figure's location in the two events agrees wherever it is defined for both events.

In section 5, we will use this ordering to define a notion called axial cumulativity which will serve the dual purposes of defining the appropriateness conditions for spatial frame adverbials and characterizing extent predicates.

4.2. Path in Motion Predicates

I assume **path** is a semantic component of both motion and extent predicates like *extend* and *zigzag* (discussed in the introduction). The two lexical axioms for *extend* and *zigzag* in (27) illustrate what I mean by saying **path** is a semantic component:

(27) a. *extend*: $\text{extend}_S(e)$ iff $\exists\pi[\textbf{path}_S(e)=\pi \wedge \text{spreading-path}(\pi)]$
iff $\text{spreading-path}\circ\textbf{path}_S(e)$
b. *zigzag*: $\text{zigzag}_S(e)$ iff $\text{zigzag-shape}\circ\textbf{path}_S(e)$

The concept of extending boils down to the existence of a path and the requirement of spreading motion (when there is motion). An event is a zigzag event along axis S if and only if there is a π such that π is the path of e and π is zigzag-shaped. A path is zigzag-shaped if and only if it has many undifferentiable points and its slope often changes signs. The concept of a zigzagging-path cross-cuts extent and event readings; it is a constraint on the relationship to the axis of change. Again, event and extent readings differ only in what axis is the axis of change. Sentence (28) provides an example:

(28) a. Mist_m zigzagged from the valley floor_v to the ridge_r
b. $\exists e[\text{zigzag}_L(e) \wedge \text{figure}(e)=m \wedge [v:r]\circ\textbf{path}_L(e)]$

The bracketed $[v:r]$ in (28b) designates a property of path functions true if they begin at v and end at r. At the minimal index of the event the fog must overlap the floor and at the maximal index the ridge.[9]

5 Paths in Scalar Predicates

In this section we return to a consideration of the role of paths in scalar predicates like *wide* and *widen*. The analysis will eventually lead to a general semantic condition on extent predicates which entails that all extent predicates incorporate the semantic component path.

We begin by revisiting the idea of adding a path component to degree-achievements like *widen*. Consider again extent readings for *widen* and *lengthen*:

(29) a. The cable lengthened in the den.
b. The carpet strip widened in the den.
c. The skirt lengthened in back.

(29a) does not have an extent reading; (29b) and (29c) do. Why should this be? The description of the problem is this: A coherent extent reading exploits two axes which must be distinct, the axis along which the measurement takes place (the *measurement axis*), and the axis along which the measurement varies (the axis of reference). For cables, the length (measurement) axis is perpendicular to any circular cross-section; and an attempt to use that measurement axis as the axis of reference, (29a), is infelicitous. (29b) remedies the problem, because width measurement uses the cross-section axis, and cross section width may vary along the carpet's length axis. (29c) remedies the problem in a different way. Skirt length is measured on the vertical axis, and that measurement can vary along a front-to-back axis.

The formal device by which we introduce change with respect to space is the increase$_{\mathrm{L}}$ operator, which maps spatial states to spatial state changes. We can flesh out these intuitions about axes in the form of a condition that holds for all states to which increase$_{\mathrm{L}}$ applies: We require simply that the properties that are going to change along axis L legitimately be states with respect to L, that is, that they can be static with respect to L.

Formally, we will require of such states that they be *axially cumulative*.

(30) *Axial Cumulativity* [10] A property P is cumulative with respect to axis S iff

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

The definition of axial cumulativity says that a property P is cumulative with respect to axis S iff when you sum two P-events and a path exists on axis S for that sum, then P holds of of the sum. Of course this definition only makes sense for events which are defined for a path function;

Applying this to the problem of (29): I claim cable width is axially cumulative along the cable length axis. Suppose we have two width events, σ_1 and σ_2, for cable c with length axis S, both bearing the property

$$\mathrm{P} = \lambda e[\text{figure}(e){=}c \wedge \text{wide}_S(e)(t) = [2\text{ inch}]\,]$$

If the sum of σ_1 and σ_2 along S has a well-defined path, then we have a larger event $\sigma_1 \oplus \sigma_2$ of which P is still true, that is, a larger event of a cable being two inches wide.

In contrast, properties like *wide* and *long* will never be axially cumulative along the measurement axis. An event in which a cable is 2 feet long summed along the length axis with an event in which the same cable is 2 feet long may give an event in which the cable is 4 feet long. The reader may verify that skirt length (generally measured on a vertical axis) is axially cumulative along a front-to-back axis.

Nothing in the definition of axial cumulativity limits it to scalar properties. In fact, apart from the predicates resulting from an application of increase, it seems to be a general property of all extent predicates. What it generally identifies is properties that it makes sense to say hold of a figure along an axis. If you take 2 events with covered portions of the mountainside and sum them along a joinable path, you get an event with covered portions of the mountainside. I therefore propose:

(31) *Condition on basic extent predicates*

A basic extent predicate must be axially cumulative along some spatial axis.

Under this condition *extend* and *zigzag* (along with all path-shape verbs) and *wide* can serve as basic extent predicates given the definitions in section 4.2. They are defined to allow spatial axes and and they are axially cumulative. If we assume that the path operator is the unique semantic component that relativizes properties to axes, then this condition immediately explains why extent predicates should take path arguments: a path operator provides the linguistic resources to describe the axis.

But as yet we have said nothing about *wide* to guarantee its axial cumulativity. What (31) requires is that the definition of the basic width state predicate must incorporate paths, which leads to the following:

(32) $\text{wide}_{\text{L}}(e)=\pi$ iff π : L $\rightarrow$ Distances and
π : s $\mapsto$ width $\circ$ $\textbf{path}_{\text{L}}(e)(s)$

Path returns the location of a slice of the figure at s and width returns the width of that slice. This assumes a basic width function mapping from spatiotemporal regions to degrees:

$$\text{width}(s) = d$$

The width of region s is d.[11] This definition of *wide* leads to an immediate account of the semantics of path expressions with *widen*, illustrated in (33), a repeat of (24):

(33) a. The crack widened 5 inches from the North gate to the tower.
b. $[\![\exists\, e\ \ [\text{increase}_{\text{L}}(\text{wide}_{\text{L}})(e)\text{=}[.5\,\text{in}]\ \wedge\ \text{figure}(e)\text{=}c\ \wedge$
$[\text{ng : t}] \circ \textbf{path}_{\text{L}}(e)]]\!]$

The path expressions constrain the path which in turn, according to (32) determines the slices over which the measurement is taken. The minimal point of e along axis L must overlap the north gate and the maximal point must overlap the tower. The difference in width is measured between those two path extremes, and must be a half-inch.

Note that axial cumulativity is just the spatial analogue of Zwarzian cumulativity, which Zwarts motivates as a way of accounting for the aspectual properties of motion predicates; his account very naturally transfers over to the kind of spatial aspectual facts we saw in (10), if we assume, following the pattern of Zwarts's account, that the spatial adverbial modifier *in + spatial interval* requires a **non-cumulative event property.** In contrast to *5 inches wide*, *widen 5 inches* is not axially cumulative and will therefore be compatible with adverbial spatial modifiers like *in 20 feet*.

Summarizing: in this section we have proposed a general semantic condition on basic extent predicates, that they be axially cumulative. This entails that basic extent predicates are defined to hold along spatial axes, and that entails path expressions can be used to describe those axes.

We have also completed our account of *wide* and *widen*, showing how the truth conditions of *wide* and thus *widen* link up with those of path expressions. As a side effect, we have a natural account of the aspectual properties of *widen*.

6 Conclusion

The bones of this account are as follows: (a) In order for a property to be an extent property, a necessary condition is that it be a static property of an event along a spatial axis, more precisely, that it be axially cumulative;[12] (b) Predicates like *cover*, *extend*, *zigzag* and *wide* are all basic extent predicates. The verbs also allow temporally indexed paths, and therefore also have event readings; (c) The verb *widen* is also an extent predicate, but a derived one. The *increase* operator produces predicates describing change along both spatial and temporal axes

We have thus proposed preliminary answers to all the basic questions in (13). We have semantically characterized extent predicates and that characterization requires that the figures in extent readings be extended a long a spatial axis. We have accounted for the correlation with path modifiers and we have made sense of the notion of change with respect to space, and shown how a stative predication like an extent reading for *widen* can preserve aspectual properties.

The central claim of this analysis is that the spatial axes of reference available in various constructions in the language of space are available for use as axes of change. Two distinct "borrowings" of axes of reference have been described: first, for cases like *zigzag* and *extend*, lexical change functions tracking path in time may be extended to track change path in space, or perhaps vice versa; second, an operator measuring the difference in change function values in time, *increase*, may be extended to measure change along the spatial dimension. The analysis is thus a semantic extension analysis. Forms specialized in meanings in one domain are extended to others. An issue for another paper is whether extent readings, at least in the case of degree achievement verbs, constitute a meaning extension that moves in the opposite direction from most space-time extensions, that is, a transition from temporal to spatial instead of the widely observed spatial to temporal transitions seen, for example, with many spatial prepositions (Traugott 2002).

In choosing *wide* as our central example, we have chosen an adjective for which both axes of reference and axes of measurement are well-motivated; but, as claimed in the introduction, extent readings for degree achievement verbs also occur for non-spatial scales:

(34) The sky pinkened at the horizon.

Whenever the concept of a scale value varying in space, and thus along an axis of reference, makes sense, extent readings are possible.

One of the chief results of this paper is that the state/event distinction is orthogonal to the static/changing distinction. This opens up the possibility of aspectual variation among state predicates. Consider (2a) again):

(35) Fog *gradually* covered the city. (event reading only)

Clearly *gradually* is incompatible with the extent reading of *cover*. This is in contrast to extent readings for *widen*, with which *gradually* works quite well, as seen in example (9). Thus among extent predicates we clearly have differences in aspectual properties. A potential account of this particular difference might be available if, as I have claimed, *widen* has an *increase* operator as a semantic component, and if *gradually* requires such a component, but this is only an account of the contrast if *cover* does not have such a component, and there are good reasons to think *cover* does. First, there is good reason to think it is a degree achievement verb (primarily that its close semantic cousin *fill* has an associated adjective); second, there is the fact that is evident in (35), that *cover* is perfectly compatible with *gradually* on its event reading, and it would be attractive to account for this fact with the use of an *increase* operator as well. What (35) seems to show is that the aspectual nature of *cover* changes between event and extent readings. Thus, although the cases of event/extent ambiguity treated in this paper have been analyzed without a change of sense, it is not clear that all such ambiguities can be.

Finally, a central feature of this account has been the use of change functions much like those in Kennedy (1999), Kennedy and McNally (1999), and HKL. In the case of *wide*, the function was simply imported from the HKL analysis, a function from indices to elements of a scale; in the case of *zigzag* and *extend*, it was a function from indices to locations. A uniform account of alternations between event and extent readings was made possible because all that was required was a change in the domain of the change function. Thus, the present work can be thought of as further motivation for the idea of change functions in the analysis of adjectives and verbs. In particular, if change functions continue to prove useful in the analysis of motion predicates, they provide an example of a motivated change function whose range is not a scale.

Endnotes

[*] I am grateful to the audience of SALT XV for numerous fruitful questions and to anonymous SALT referees for helpful comments. I am also grateful to audiences at the Leipzig event shop workshop and at UCSD for discussions of earlier versions of this work, and I owe special thanks to Farrell Ackerman, Chris Barker, Charles Fillmore, Andrew Kehler, Rob Malouf, and members of the FrameNet group for discussion. This work was supported in part by NSF grant ITR/HCI #0086132.

[1] Potential counterexamples are *surround* and *envelope*. But it seems reasonable to suppose that these two cases involve an incorporated path.

[2] Thanks to Daniel Buring, during the presentation, for this illuminating example.

[3] Example (12a) is from Talmy (1996). Thanks to a member of the Salt audience for pointing out example (12b).

[4] Indeed, the English preposition-choice and Finnish case facts that Fong (1997) is trying to account for seem to be another example of such a phenomenon.

[5] The need for an axis of reference for the simple adjective is clear. Consider

(i) The boulder/cabinet is a yard wide.

This example shows that the extrinsic/intrinsic distinction for axes of reference plays a role in width measurements. Cabinets have canonical fronts and backs, a fact which canonical width measurements are sensitive to: they must be made on an axis perpendicular to front/ back. Boulders do not; thus an orientation for a width measurement must be supplied by context.

[6] $\mathcal{T}(e)$ is Krifka's (1998) spatiotemporal trace function.

[7] The idea of representing paths through the use of functions from events to times to locations is anticipated in Verkuyl 1978.

[8] This is a granularity restriction on e, the event. For spatially indexed paths, if the figure f visits s several times, slice(f, s) is a disconnected spatiotemporal location identifying the intersection of Tplane(S, s) with f at each of f's visits. Connectedness forces e to be small enough to include just one of f's visits.

[9] We assume a PP like *from Boston* denotes a property of paths:

$$\begin{aligned}[\![\text{from Boston}_{\text{S}}]\!] &= \lambda\pi[\pi(\text{START}_{\text{S}}(e)) \text{ overlaps Boston}] \\ &= \text{a property true of a path if the path evaluated at minimal member of its domain overlaps Boston}\end{aligned}$$

[10] The idea of emphasizing cumulativity in the context of paths is due to Zwarts (2005), who argues that cumulativity is the relevant concept for identifying telicity where paths are concerned, and argues against Krifka's notion of quantization (Krifka 1992,1998). The arguments appear to carry over to this construction of paths, and the definition of cumulativity given is a translation of Zwarts's notion to this framework. Below I apply it to the problem Zwarts intended it for, telicity.

[11] We omit the axis of measurement (generally perpendicular to the axis of reference). Given a rectangular cross-section of a file cabinet, the axis of measurement decides among the two possible directions that might be the width.

[12] The notion of spatial axis was critical to the account proposed in Jackendoff (1996). For Jackendoff, extent readings are projections of an event along a spatial axis. Although Jackendoff does not address degree achievement cases or the possibility of aspectual structure among spatial predicates, there are a number of convergences between his work and the proposal here.

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