

From change to value difference *

Ashwini Deo
Yale University

Itamar Francez
University of Chicago

Andrew Koontz-Garboden
University of Manchester

Abstract Degree achievements and directed motion verbs are standardly taken to describe events in which an individual undergoes change over time. The spatial uses of these verbs, giving rise to what are known as their *extent* readings, indicate that a temporal change based semantics is not general enough to capture their behavior. In this paper, we introduce a further range of facts that argues for a fully general analysis of the meaning of degree achievements and directed motion verbs in terms of *value difference* rather than temporal change. These verbs are uniformly analyzed as intensional verbs that take functional arguments and encode a difference in the value of this argument over a contextually given ordered domain. This analysis accounts naturally for their interaction with a range of adverbial modifiers.

Keywords: Degree achievements, lexical semantics, change of state, functional readings, individual concepts, context dependence

1 Introduction

Degree achievements and verbs of directed motion are traditionally viewed as describing events in which an individual undergoes change over time (e.g. Dowty 1979; Declerck 1979; Hay, Kennedy & Levin 1999; Rappaport Hovav 2008; Kennedy & Levin 2008). Degree achievements, such as *widen*, *narrow*, or *darken*, describe change in the degree to which an individual exhibits a property, inherited from the adjectival source if there is one, over time. Directed motion verbs, such as *ascend*, *descend*, *fall*, or *rise*, describe change in the position of an individual along some path over time. Typical examples are given in (1).

- (1) a. The river widened. event of the river changing width

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- b. The soup cooled. event of the soup changing temperature
- c. The balloon rose. event of the balloon changing vertical distance

Events of change in an individual over time form the basis for the semantic analysis of these classes of verbs. For example, [Kennedy & Levin \(2008\)](#) take a degree achievement to denote a measure of change function, a function that “takes **an object** x and **an event** e and returns the degree that represents the amount that x **changes** in the property measured by m **as a result of participating in** e ” (2008:173, emphasis ours).

There are well known cases, however, which are not intuitively described as involving change in an individual over the course of, or as a result of participating in, an event. One example is so-called *extent* readings ([Langacker 1986](#); [Sweetser 1997](#); [Gawron 2009](#); [Koontz-Garboden 2010](#)) of degree achievements, as exemplified in (2).

- (2) The trail narrowed at the summit.

On the extent reading, which is the most natural reading for (2), the sentence does not describe an event in which the trail changes in width over time, and is in fact consistent with the trail having stayed the same width throughout its history. Such readings do not involve measuring change over the temporal duration of an event, but rather over the spatial extent of an individual—in the case of (2), the trail.

Somewhat more dramatic are uses of degree achievements that not only do not entail temporal change, but do not to entail change in any individual whatsoever, whether over time or space. The attested example in (3) with *flatten* is illustrative.

- (3) [In children with fetal alcohol syndrome] the divot or groove between the nose and upper lip flattens with increased prenatal alcohol exposure.

The sentence in (3) does not describe change in any single individual divot. Rather, it describes a difference in width between the divots of different individuals. In particular, it states that individuals who have different degrees of prenatal exposure to alcohol have different divot widths. Such uses of degree achievement and directed motion verbs (for which we henceforth use *degree achievements* as a cover term) have not figured in the literature. Currently available analyses of the lexical semantics of degree achievements cannot capture them, since, with rare exceptions noted below, they all entail change in an individual.

The goal of this paper is to present an explicit and uniform semantics for these verbs which accounts for their full range of interpretations as well as for their behavior with a range of adverbial modifiers. Our main analytical claims are the following:

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- i. The event-based view of change of state must be generalized to an interval-based notion of *value difference*, a change in the value of a function over a contextually given ordered domain, with change in an individual over time/space as a special case.
- ii. Degree achievement verbs are uniformly intensional, taking a *generalized individual concept* argument, as argued by Montague (1973), Partee (1974) and Löbner (1981) for the verb *rise* in the temperature paradox.
- iii. The meaning of degree achievements is radically context dependent, with major components determined by setting of contextual parameters.

The paper begins by making the empirical case for generalizing change to value difference, laying out four classes of readings that degree achievement verbs can have. Section 3 presents our analysis, showing how it captures all of these classes, as well as the interaction of degree achievements with an array of modifiers, going beyond the well known temporal cases discussed extensively in the literature. We make some novel observations about the effects of modifiers in contexts that do not involve change in an individual, and demonstrate how the analysis captures them. Section 4 concludes the paper.

2 Beyond events, individuals, and change

This section documents a range of readings available to degree achievement verbs which cannot be captured in terms of individuals undergoing change over the course of an event (or as a result of participating in an event), and which therefore motivate the generalized, interval-based analysis proposed in section 3.

2.1 Spatial extent readings

Spatial extent readings can be characterized as those in which change is construed as a difference with respect to some attribute between the subparts of an object extended in space. The data in (4) exemplify this reading.

- (4)
- a. His skin darkens on his right leg near the femoral artery.
 \rightsquigarrow His skin is darker on his right leg than it is elsewhere.
 - b. The road narrows at the end.
 \rightsquigarrow The road is narrower at the end than before the end.

Gawron (2009) characterizes the required generalization of the notion of change that examples like these motivate as *functional change*, noting that:

Functional change is the existence of some correlation between two ordered domains, and change with respect to time is a special case of that. (Gawron 2009:16)

Koontz-Garboden (2010) shows that once this is recognized, Kennedy and Levin's (2008) analysis of degree achievements can be extended to extent readings. For example, (4b) is true if there is an eventuality in which an individual, the road, changes in width over a spatial interval. Further examples are given in (5).

- (5) a. The road widens between San Francisco and San Jose.
- b. After the merge of the three forks the river flattens and travels through Grant, Cleveland, Bradley, and Ashley counties.
- c. After this, the wall narrows to a foot wide with steep vertical drops on either side, sometimes hundreds of yards down.
- d. The cliffs sink as the plain flattens, and green, sloping banks of diluvium take their place.

2.2 Abstract extent readings

In abstract extent readings, as in the spatial extent readings, change in an individual happens, but the change is neither in space nor in time. This kind of reading is exemplified by the data in (6).

- (6) a. The plot thickens in chapter three.
 style="margin-left: 2.5em;">↪The plot is thicker in chapter three than before chapter three.
- b. The script weakens towards the end.
 style="margin-left: 2.5em;">↪The script is weaker towards the final part than at prior parts.

Such examples can be construed as differences with respect to some attribute (thickness, weakness) between the subparts of an extended individual (the plot, the script) along some abstract structuring dimension, a storyline in the case of both (6a,b). More examples of the same general kind are given in (7).

- (7) a. The album lifts up with the second track and single "Hurricane."
- b. The story disintegrates towards the end and the last level is pretty crap.
- c. The song improves when it goes back to the main beat.

2.3 Kind readings

That degree achievements can express change that is not internal to a single individual and does not occur as a result of participating in an event is made clear by what we call kind readings, exemplified by the data in (8).

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- (8) a. The *strobiformis* cones in Mexico gradually lengthen as you go south along the Sierra Madre Occidental through Sonora, Chihuahua and Durango, the longest cones being in Durango. **Spatial case**
- b. Wolves increased over most of the Nelchina caribou range, especially in subunit 13A, where wolf numbers in 1998 and 1999 were the highest observed in more than 25 years. **Temporal case**

In these examples, change is construed as a difference with respect to some attribute between instances of a kind along some structuring dimension – often space and time. (8a), for example, describes a difference in length between instances of the *strobiformis cone* kind at different locations along the Sierra Madre. (8b) describes a difference in quantity between instances of the *wolf* kind at different temporal intervals. Additional examples are given in (9).

- (9) a. Ants increase as you move to the south. In the Scandinavian countries there are about 20 species.
- b. Notice that the trees gradually thin out until there is no longer a canopy above you.
- c. When the economy is flourishing, hemlines rise, meaning one would see more miniskirts, and when the situation is deteriorating, hemlines drop, perhaps even to the floor.

These examples parallel familiar data noted by Carlson (1977), and discussed by Sweetser (1997) and Zwarts, Hendriks & de Hoop (2005), but with degree achievements replacing the comparative adjectives, which they focus on.¹

- (10) a. Wolves **get bigger** as you go north of here. (Carlson 1977)
- b. The wells **get deeper** as you go down in the road. (Sweetser 1997)

Zwarts et al. (2005) note that sentences like (10) require intensional arguments, and analyze them as involving “reflexive comparison” – comparing an extended individual to itself. Although we agree that they require an intensional argument, there does not seem to us to be motivation for assuming that degree achievements, which do not involve comparative morphology, involve a comparative operation. While the semantic analogy is clear for many degree achievements, it is less so, for example, for verbs of directed motion. Be that as it may, examples we discuss in

¹ Sweetser (1997) claims that examples like (10b) cannot be rendered with a degree achievement. Such examples are, however, well-attested. A naturally occurring example is (i):

- (i) In general, the wells **deepen** toward the south and east, as is illustrated by the depths of the wells belonging to the San Antonio waterworks.

the next section are difficult to construe in terms of comparison of an individual to itself.

2.4 Functional readings

Functional readings of degree achievements are somewhat more dramatic and their extent and generality has not been noticed in the literature. These are readings in which the verb describes a difference with respect to some attribute between different entities that seem to be determined by some relation to elements of an ordered domain. For example, the sentence in (11) is about the difference in flatness between the divots of children with varying prenatal exposure to alcohol. We call these readings ‘functional’ because we take the subject of the verb to be functional. In (11), *the divot* denotes a function from individuals to their divot, and the sentence asserts that this function yields a flatter divot for individuals with more extended prenatal exposure to alcohol.²

- (11) In children with fetal alcohol syndrome, the divot or groove between the nose and upper lip flattens with increased prenatal alcohol exposure.

Additional examples of the same kind are given in (12).

- (12) a. Fish ears grow with increased CO₂.
 b. The ratio of these providers to the population worsens as rurality increases.
 c. The resolution improves with the distance between the first and second detector.
 d. Cooperation grows with the severity of punishment for mutual defec-tion.

Functional readings clearly cannot be analyzed in terms of a Kennedy and Levin (2008) style function, measuring change in an individual over the course of an event. They are also not straightforwardly analyzed in terms of the reflexive comparison analysis of Zwarts et al.’s (2005). For example, there is no sense in which (11) can be said to involve comparing any divot to itself. Functional readings are most similar to the reading involved in temperature sentences like (13). As observed and discussed by Montague (1973) and Löbner (1981), *the temperature* in (13) cannot

² In Deo, Francez & Koontz-Garboden 2011, we observe that functional readings extend from verbs to the adjectives derived from them by the derivational suffix *-ed*. An example is given in (ii).

- (ii) Fetal alcohol syndrome causes facial abnormalities, including **flattened** cheekbones ... and a **flattened** groove between the upper lip and nose.

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be taken to refer to a particular temperature, but rather must be read intensionally, i.e. functionally, avoiding substitutivity failures.

(13) The temperature is rising.

We argue below that a general account of degree achievements calls for assuming an intensional argument in all cases.

2.5 Summary

The full range of uses of degree achievements requires moving from a semantics based on change in an individual over the course of an event to a more abstract semantics, based on comparing values of functions at different points along an ordered domain.

3 Analysis

The analysis we propose generalizes the standard individual-and-event based semantics for degree achievements to a *difference*-based semantics: degree achievements and directed motion verbs uniformly describe a difference in the value of some function over an interval of some ordered domain. Change in an individual over the temporal course of an event comes out as a special case.

The core idea is the following. All degree achievements and directed motion verbs have as their subject argument a function from an ordered domain to individuals. For example, a name like *John*, ordinarily taken to denote a simple individual, is analyzed as a function from temporal intervals to temporal stages of John, and a noun phrase like *the road* is analyzed as a function from spatial intervals to parts of the road. A simple, positive sentence containing a degree achievement/directed motion verb is true iff there is an interval of some contextually given ordered domain such that the value of the functional argument at its minimal initial subinterval differs from its value at the minimal final subinterval with respect to some property or location on a path, specified by the verb.

3.1 The semantics

An *attribute ordering*, defined as in (14), gives the relevant ranking of individuals with respect to an attribute encoded in the meaning of a degree achievement or directed motion verb.³

³ This notion can be extended to achievements more generally: if δ is a non-gradable attribute, $a <_{\delta} b$ iff b exemplifies δ and a does not.

- (14) **Attribute ordering:** An attribute ordering \leq_δ is a preorder on the domain of individuals E , which orders individuals based on the degree to which they exemplify an attribute δ , or their location on a given directed path.

In the case of deadjectival degree achievements, attribute orderings are derived from measure functions denoted by adjectives (Kennedy 1999, 2007). For instance, if **wide** is the measure function assigning to all individuals their widths, then the attribute ordering of individuals by width is related to measures derived from the measure function as in (15).⁴

- (15) $a <_{\text{wide}} b$ iff **wide**(a) < **wide**(b)

In directed motion verbs, attribute orderings are derived from location functions along an orientated axis. A verb like **rise** encodes a function from individuals to their location on a vertical axis with an upward orientation, while a verb like **descend** encodes its counterpart on the downward orientation. For lack of space we do not offer a formalization of motion verbs here.

An **axis** is a linearly ordered set of entities in any ontological domain (Gawron 2009). The argument of a degree achievement is a *generalized individual concept*, or *gic*, a function from axes to individuals.

- (16) **Generalized individual concept (gic):** A gic f is a function from any axis α to the domain of individuals E .

The notion of change over the course of an event is replaced by *value difference*, defined in (17), a difference in the degree to which the values of a function at different parts of an axis exemplify a property.

- (17) **Value difference:** A gic f shows a value difference relative to an axis A and an attribute ordering δ iff there are two intervals a, b in A (or subsets of A) such that $a < b$ and $f(a) <_\delta f(b)$.

Degree achievements (and possibly other COS verbs, see Deo et al. 2011) denote a relation between a gic and a contextually given axis (interval). The difference relation holds iff the gic shows a value difference between the minimal initial and the minimal final subintervals of the axis, i.e. iff values of the gic at the two intervals differ with respect to the lexically specified attribute. An example denotation for the degree achievement verb *widen* is in (18).

⁴ In the case of degree achievements that are not deadjectival, we simply assume that their lexical semantics is built on a measure function that does not happen to be the denotation of an adjective that the verb is derived from. This measure function may or may not be the denotation of some adjective.

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$$(18) \quad \llbracket \text{widen} \rrbracket = \lambda f_{(\tau,e)} . \lambda i_{\tau} . f(\text{init}_i) <_{\text{wide}} f(\text{end}_i)$$

(18) says that a gic f widens along a contextually given axis i iff the value of the gic at the beginning of the axis is wider than its value at the end of it. The remainder of the paper shows how this denotational schema captures the full range of data laid out in §2, as well as facts, several newly observed, about the interaction of degree achievements with adverbial modifiers.

3.2 The standard temporal case

The familiar case in which an individual changes over the course of an event, exemplified in (19), is a special case of value difference in which the contextual axis is temporal and the gic is a function from temporal intervals (type t) to stages of an individual. The derivation of (19) is given in (20), where *the soup* is interpreted as a gic f_{soup} , a function from temporal intervals to temporal stages of the soup.⁵

(19) The soup cooled.

$$(20) \quad \begin{array}{ll} \text{a.} & \llbracket \text{cool} \rrbracket = \lambda f_{(t,e)} . \lambda t_t . f(\text{init}_t) <_{\text{cool}} f(\text{end}_t) \\ \text{b.} & \llbracket \text{cool}(\text{the soup}) \rrbracket = \lambda t_t . f_{\text{soup}}(\text{init}_t) <_{\text{cool}} f_{\text{soup}}(\text{end}_t) \end{array}$$

Sentence radicals – untensed, aspectually unmodified verbs with their gic argument saturated – are taken to denote properties of axes. We call these **difference descriptions**. (20b) exemplifies a difference description, denoting a property that holds of a temporal interval if the soup is cooler at the end of this interval than it is at the beginning. Past tense instantiates the difference description at the contextually determined past interval t^* (assuming an anaphoric theory of tense, as in e.g. Partee 1973). The truth conditions for (19), given in (21), say that (19) is true iff the soup at the beginning of t^* is less cool than the soup at the end of t^* .

$$(21) \quad \llbracket (19) \rrbracket = 1 \text{ iff } f_{\text{soup}}(\text{init}_{t^*}) <_{\text{cool}} f_{\text{soup}}(\text{end}_{t^*})$$

3.3 Extent readings

Extent readings arise when (i) the contextually supplied axis is the spatial extent of an object that extends in space, and (ii) the gic is a function from spatial intervals (type σ) to spatial parts of an extended individual. On this view, the meaning for the sentence in (22) is derived as in (23): *the road* is interpreted as a gic f_{road} , a function from the spatial extent of the road L_{road} to its parts.

(22) The road narrows at the end.

⁵ Alternatively, it could be interpreted as a constant function from times to the soup.

- (23) a. $\llbracket \text{narrow} \rrbracket = \lambda f_{(l,e)} . \lambda l_{\sigma} . f(\text{init}_l) <_{\text{narrow}} f(\text{end}_l)$
 b. $\llbracket \text{narrow}(\text{the road}) \rrbracket = \lambda l . f_{\text{road}}(\text{init}_l) <_{\text{narrow}} f_{\text{road}}(\text{end}_l)$

The sentence radical in (23b) again denotes a difference description – the set of subintervals of L_{road} such that the road is more narrow at their end than at their beginning. *at the end* is analyzed as a difference description modifier, with the denotation in (24). α is a variable over difference descriptions, and EOR is a small-enough final subinterval of L_{road} .

- (24) $\llbracket \text{at the end (of the road)} \rrbracket = \lambda \alpha . \lambda l . \text{end}_l \subseteq \text{EOR} \ \& \ \alpha(l)$

The meaning of the modified sentence radical in (22), before composition with tense, is as in (25).

- (25) $\lambda l . \text{end}_l \subseteq \text{EOR} \ \& \ f_{\text{road}}(\text{init}_l) <_{\text{narrow}} f_{\text{road}}(\text{end}_l)$

Thus, (22) asserts that there is some spatial interval whose intersection with the end of the road is less narrow at its beginning than at the end.

3.4 Kind readings

In kind readings, re-exemplified in (26), the contextually supplied axis varies across cases (the simplest being spatial). The *gic* associated with a kind is a function from the axial intervals to the maximal plural individual in E that instantiates the kind at that interval.

- (26) The strobiformis cones in Mexico gradually **lengthen** (as you go south along the Sierra Madre Occidental...).

Ignoring *as*-modifiers for now, we propose the following truth conditions for the simplified version of (26) in (27).

- (27) The cones lengthen in Mexico.

The cones is interpreted as f_{cones} , a function from locations to the maximal plural individual exemplifying the strobiformis cone kind at that location. *lengthen* has the denotation in (28a). The sentence radical of (27) denotes the difference description in (28b). That is, it denotes those spatial intervals such that the cones at their beginning are shorter than those at their end. The length of a plural individual is assumed to be the average over the measures of the atomic individuals constituting it.

- (28) a. $\llbracket \text{lengthen} \rrbracket = \lambda f_{(\sigma,e)} . \lambda l_{\sigma} . f(\text{init}_l) <_{\text{long}} f(\text{end}_l)$

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$$\text{b. } \llbracket \text{lengthen}(\text{the cones}) \rrbracket = \lambda l_{\sigma}.f(\text{init}_l) <_{\text{long}} f(\text{end}_l)$$

The modifier *in Mexico*, like other modifiers, is treated as a difference description modifier.

$$(29) \quad \llbracket \text{in Mexico} \rrbracket = \lambda \alpha. \lambda l_{\sigma}. \text{end}_l \subseteq \text{Mexico} \ \& \ \alpha(l \cap \text{Mexico})$$

The meaning of (27) is in (30). In words, it says that there is a region ending somewhere in Mexico such that the cones at its end are longer than at its beginning.

$$(30) \quad \llbracket \text{in Mexico}(\text{lengthen}(\text{the cones})) \rrbracket = \\ \lambda l_{\sigma}. \text{end}_l \subseteq \text{Mexico} \ \& \ f_{\text{cones}}(\text{init}_l) <_{\text{length}} f_{\text{cones}}(\text{end}_l)$$

3.5 Functional readings

Functional readings, such as (11) from above, repeated in (31), are the ones for which the advantage of the move to value difference is most apparent, since they cannot be captured by existing approaches, as discussed above.

$$(31) \quad (\text{In children with fetal alcohol syndrome}) \text{ the divot } \mathbf{flattens} \text{ with increased prenatal alcohol exposure.}$$

On our analysis, these are readings in which the contextual axis is an ordered set, possibly of discrete entities, including people, as in (31), and where the gic is a function from this ordered set to individuals, often an $\langle e, e \rangle$ -type function. Functional readings are special in that the axis must be constructed by using modifier information for retrieving the set of individuals and the ordering.

In (31), for instance, *the divot* is interpreted as the function f_{divot} from individuals to their divot. The verb *flatten* has the denotation in (32a), where $A^<$ is an ordered set of individuals, yielding (32b) for the meaning of the unmodified sentence radical.

$$(32) \quad \text{a. } \llbracket \text{flatten} \rrbracket = \lambda f_{\langle e, e \rangle}. \lambda A_{et}^{<}. f(\text{init}_A) <_{\text{flat}} f(\text{end}_A) \\ \text{b. } \llbracket \text{flatten}(\text{the divot}) \rrbracket = \lambda A^{<}. f_{\text{divot}}(\text{init}_A) <_{\text{flat}} f_{\text{divot}}(\text{end}_A)$$

The modifier *In children with fetal alcohol syndrome* restricts the possible values of A to sets C of children with fetal alcohol syndrome, as in (33).

$$(33) \quad \llbracket \text{in children with fetal alcohol syndrome}(\text{flatten}(\text{the divot})) \rrbracket = \\ \lambda C^{<}. f_{\text{divot}}(\text{init}_C) <_{\text{flat}} f_{\text{divot}}(\text{end}_C)$$

Finally, the modifier *with increased exposure* has the denotation in (34a) and applies, as in (34b) to the difference description in (33), restricting it to intervals of C

ordered by the amount of prenatal exposure to alcohol.

- (34) a. $\llbracket \text{with increased exposure} \rrbracket = \lambda \alpha. \forall x, y \in C^{<exp} (x <_{exp} y \rightarrow \alpha([x, y]))$
 b. $\llbracket \text{with increased exposure} \rrbracket$
 (in children with fetal alcohol syndrome(flatten(the divot))) $\llbracket =$
 $\forall x, y \in C^{<exp} (x <_{exp} y \rightarrow f_{divot}(\text{init}_{[x,y]}) <_{flat} f_{divot}(\text{end}_{[x,y]}))$

In words, (31) is true iff for any two children suffering from the syndrome, if one had longer prenatal exposure to alcohol than the other, then she has a flatter divot.

3.6 More modifiers

Degree achievements occur with a wide range of modifiers, some of which we have already discussed in the previous sections. In this section we show that the generalized denotations for these verbs provide an elegant account of the interaction of such verbs with familiar aspectually sensitive modifiers like *for*-PPs, *between*-PPs and *again* on a range of axes: temporal, spatial, informational, and more. The semantics of such modifiers has, to our knowledge, only been discussed in the literature in the context of verbs describing changes over time.

3.6.1 For-PPs

For-PPs constrain the measure of **axial** intervals. The examples in (35) illustrate axes of different types: temporal (35a), spatial (35b), and informational (35c,d).

- (35) a. The soup cooled *for an hour*. temporal axis
 b. The road widens *for two miles*. spatial axis
 c. The plot improves *for a few chapters*. informational axis
 d. The album slows down *for several acoustic songs*. informational axis

Building on Dowty 1979; Moltmann 1991 and Deo & Piñango 2011, *for*-PPs denote universal quantifiers over relevant subintervals of an interval. Concretely, our analysis takes *for*-PPs to quantify over a contextually determined regular partition \mathcal{R}_A^c of the measure-interval (Deo & Piñango 2011).⁶ The *for*-PP takes a differ-

⁶ For any axial interval A , a *regular partition* \mathcal{R}_A of A is the set of non-empty, collectively exhaustive, mutually exclusive, equimeasured subsets of A . For any \mathcal{R}_A^c , the *partition measure*, which is the measure of each of its cells, is determined in context.

- (iii) \mathcal{R}_A is a regular partition of i if \mathcal{R}_A is a set of intervals $\{j, k \dots n\}$ such that
 a. $\bigcup \{j, k \dots n\} = i$ collectively exhaustive
 b. $\forall j, k \in \mathcal{R}_i \rightarrow j \cap k = \emptyset$ if $j \neq k$ mutually exclusive
 c. $\forall j, k \in \mathcal{R}_i \rightarrow \mu(j) = \mu(k)$

ence description as an argument and returns a constrained difference description in which every cell in the partition COINCides with an interval instantiating the original description. This general schema for the meaning of *for*-PPs is given in (36), with the COINCidence relation defined in (37). In prose, an interval $i \subseteq A$ and a difference description α are in the COINCidence relation if α is instantiated within a final subinterval of i . The final subinterval requirement allows for the two readings of difference verbs observed with *for*-PPs – the *constant* reading and the *variable* reading, which we describe below.

$$(36) \quad \llbracket \text{for } x\text{-units} \rrbracket = \lambda \alpha_{(\tau, t)} . \lambda A_{\tau} . \text{unit}(i) = n \ \& \ \forall A' : A' \in \mathcal{R}_A^c \rightarrow \text{COIN}(\alpha, A')$$

$$(37) \quad \text{COIN}(\alpha, i) = \exists i' : \alpha(i') \ \& \ i \subseteq_{\text{fin}} i'$$

The familiar case of temporal modification as in (35a) obtains when the axial interval is temporal and is generated as in (38). In words, the *for*-PP modified difference description in (38b) denotes one-hour long intervals whose every contextually determined cell is a final subinterval of some interval that instantiates the value difference.

$$(38) \quad \begin{aligned} \text{a.} \quad & \llbracket \text{for an hour} \rrbracket = \lambda \alpha_{t_1, t} . \lambda t_1 . \text{hours}(t) = 1 \ \& \ \forall t' : t' \in \mathcal{R}_t^c \rightarrow \text{COIN}(\alpha, t') \\ \text{b.} \quad & \llbracket \text{for an hour}(\text{cool}(\text{the soup})) \rrbracket = \\ & \lambda t_1 . \text{hours}(t) = 1 \ \& \ \forall t' : t' \in \mathcal{R}_t^c \rightarrow \\ & \quad \exists t'' : f_{\text{soup}}(\text{init}_{t''}) <_{\text{cool}} f_{\text{soup}}(\text{end}_{t''}) \ \& \ t' \subseteq_{\text{fin}} t'' \end{aligned}$$

The derivation of the spatial cases is the same, except with respect to the nature of the axial interval. The derivation of (35b) is as in (39). Similarly for the informational cases in (35c) and (35d), which involve axes of ordered informational units, chapters of a book or songs on an album.

$$(39) \quad \begin{aligned} \text{a.} \quad & \llbracket \text{widen}(\text{the road}) \rrbracket = \lambda l_{\sigma} . f_{\text{road}}(\text{init}_l) <_{\text{narrow}} f_{\text{road}}(\text{end}_l) \\ \text{b.} \quad & \llbracket \text{for two miles}(\text{widen}(\text{the road})) \rrbracket = \\ & \lambda l_{\sigma} . \text{miles}(l) = 2 \ \& \ \forall l' : l' \in \mathcal{R}_l^c \rightarrow \\ & \quad \exists l'' : f_{\text{road}}(\text{init}_{l''}) <_{\text{wide}} f_{\text{road}}(\text{end}_{l''}) \ \& \ l' \subseteq_{\text{fin}} l'' \end{aligned}$$

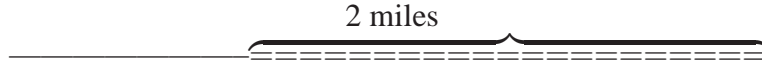
All of the examples in (35) are ambiguous between two readings mentioned above. The *constant* reading is the one in which the value difference remains constant across the axial interval relative to an immediately prior interval. For instance, (35b), on the constant reading, describes a situation in which the road widens (right) before the 2 mile section (corresponding to the axial interval) and then remains of constant width across the two mile interval. This is shown graphically in (40).

(where $\mu(x)$ stands for the Lebesgue measure of x).

equimeasured

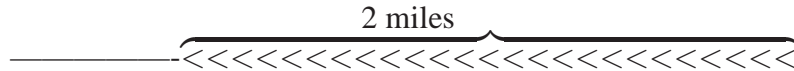
On our meaning for *for*-PPs, this reading can arise when the value difference is determined relative to a single initial interval for all partition cells – i.e. l'' does not vary (wide scope existential) with each l' .

(40) **Constant reading:**



In contrast, the *variable* reading arises when l'' is allowed to vary across partition cells l' . (35b), on the variable reading, describes a situation in which the road gradually becomes wider and wider over the two mile interval, and of course, that is the most natural reading of the *for*-modified sentence in (35a). The variable road-widening case is illustrated graphically in (41) (the $<$ sign indicates widening)

(41) **Variable reading:**



3.6.2 Between PPs

Between-PPs, illustrated in (42), are frame adverbials that constrain the location of the axial intervals.

- (42) a. A section near X2300 darkened *between August 23 and September 2*.
 b. The road narrows *between San Francisco and San Jose*.
 c. The plot thickens *between Chapter 12 and 15*.
 d. Quality of life increases *between 50-64 years*.

In each case, whether temporally (42a), spatially (42b), informationally (42c), or functionally (42d), the main thrust of *between*-PP modification is that the difference description is instantiated at some interval whose final subinterval lies in the interval introduced by the PP. This is illustrated for the spatial case (42b) in (43).

- (43) a. $\llbracket \text{between SF and SJ} \rrbracket = \lambda \alpha_{(\sigma, t)}. \lambda l_{\sigma}. \text{end}_l \subseteq [SF, SJ] \ \& \ \alpha(l)$
 b. $\llbracket \text{between SF and SJ(narrow(the road))} \rrbracket =$
 $\lambda l_{\sigma}. \text{end}_l \subseteq [SF, SJ] \ \& \ f_{road}(\text{init}_l) <_{narrow} f_{road}(\text{end}_l)$

The semantics in (43) correctly accounts for two readings of *between*-PPs, which we call the *throughout* and *containment* readings. For (42b), for example, the *throughout* reading is the one in which the road is understood to be narrower than before throughout the stretch between San Francisco and San Jose. This is illus-

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trated in (44).

- (44) **Throughout reading:**
- $$\text{=====SF} \overbrace{\text{-----}}^{\text{narrow}} \text{SJ} \text{=====}$$

On our account, this reading arises when the interval $[SF, SJ]$ is final subinterval of l , i.e. $[SF, SJ] = \text{end}_l$. The containment reading is the one in which the stretch between San Francisco and San Jose is understood to contain a narrowing – i.e. some part of that stretch is narrower than the other parts. This reading arises when end_l is a proper subset of $[SF, SJ]$. This is illustrated in (45).

- (45) **Containment reading:**

$$\text{=====SF} \overbrace{\text{-----}}^{\text{narrow}} \text{SJ} \text{=====}$$

The analysis naturally extends to functional readings with *between*-PPs, like (42d), where *quality of life* is a function from age to (average) quality of life at that age and where *between 50 and 64 years* constrains the increase in quality of life to happen over an age interval between 50 and 64, as shown in (46):

- (46) a. $\llbracket \text{between 50 and 64 years} \rrbracket = \lambda \alpha_{(\sigma, t)}. \lambda i_{\sigma}. \text{end}_i \subseteq [50, 64] \ \& \ \alpha(i)$
 b. $\llbracket \text{between 50 and 64 years}(\text{increase}(\text{QOL})) \rrbracket =$
 $\lambda i_{\sigma}. \text{end}_i \subseteq [50, 64] \ \& \ f_{\text{QOL}}(\text{init}_i) < f_{\text{QOL}}(\text{end}_i)$

3.6.3 Repetitive and restitutive *again*

The properties of *again* modification with change of state verbs are much discussed in the literature on standard temporal readings (e.g., Dowty 1979; von Stechow 1996). The data in (47) show that *again*, like other adverbial modifiers, is more accurately treated as a modifier of axial intervals. Not only does it occur in temporal modification (47a), but it also has spatial readings (47b) and abstract ones (47c).

- (47) a. The river widened *again* (after the floods). (temporal)
 b. The wall narrows *again* (at the north gate). (spatial)
 c. The gap widens *again* as students move into the cognitive challenge of secondary years. (abstract)

We propose a meaning for *again* that accounts for its cross-domain uses as well as for the two readings most familiar from the temporal literature – the *repetitive* and the *restitutive* readings. On our proposal, *again* makes both a presuppositional and an assertoric contribution. The presupposition involves considering the instantiation

of the difference description α relative to a reversed axis. Our semantics for *again* is given in (48). Given a difference description α and an interval i , $\text{again}(\alpha)(i)$ is defined if there is some interval i' that precedes i and α is instantiated at $[i, i']$. The truth-conditional component of *again* requires straightforward instantiation of α at i .

- (48) $\llbracket \text{again}(\alpha_{(\tau, t)})(i_\tau) \rrbracket$ is defined if $\exists i'_\tau : i' < i \ \& \ \alpha([i, i'])$
 If defined, $\llbracket \text{again}(\alpha)(i) \rrbracket = 1$ iff $\alpha(i)$

The presuppositional component of *again* allows us to naturally account for its repetitive and restitutive readings. Consider the spatial modification effected by *again* in (47b). This sentence has two readings. On the repetitive reading, the sentence is understood to describe a situation in which the wall starts out at some width, narrows at a later point in space, widens at an even later point, and then exhibits yet another narrowing. This reading is represented graphically in (49).

- (49) **Repetitive reading:**



On the restitutive reading, (47b) describes a different scenario, where the wall starts out as having a certain width, widens at a later point in space, and then undergoes a decrease in width. This reading is illustrated in (50).

- (50) **Restitutive reading:**



The presupposition for *again* allows for both these scenarios. The derivation of (50b) is given in (51).

- (51) a. $\llbracket \text{narrow}(\text{the wall}) \rrbracket = \lambda l_\sigma . f_{\text{wall}}(\text{init}_l) <_{\text{narrow}} f_{\text{wall}}(\text{end}_l)$
 b. $\llbracket \text{again}(\text{narrow}(\text{the wall}))(l_\sigma) \rrbracket$ is defined only if
 $\exists l'_\sigma : l' < l \ \& \ f_{\text{wall}}(\text{init}_{[l, l']}) <_{\text{narrow}} f_{\text{wall}}(\text{end}_{[l, l']})$
 If defined, $\llbracket \text{again}(\text{narrow}(\text{the wall}))(l) \rrbracket = 1$ iff
 $f_{\text{wall}}(\text{init}_l) <_{\text{narrow}} f_{\text{wall}}(\text{end}_l)$

The repetitive reading arises if, in addition to the conditions specified in (51b), there is also an interval l'' such that $l'' < l' < l$ and $\alpha(l'', l')$. The restitutive reading arises when there is no such interval. The same analysis applies straightforwardly to the temporal (47a) and informational (47c) cases.

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3.6.4 As-modification

Many of the examples of atemporal difference discussed above have *as* modifiers, illustrated in (52).

- (52) a. The cones lengthen *as you go south*.
 b. Performance gap between ELL and Non-ELL students reduces *as the level of language demand of assessment decreases*.
 c. In the group of native Swedes, the proportion of daily smokers reduces *as the level of education increases*.
 d. U.S. Trade Deficit narrows *as the economy slows*.

An *as*-modifier, much like the *with* modifiers discussed in §3.5, quantifies over pairs $\langle i, j \rangle$ of ordered subintervals of an axis, and says that the interval $[i, j]$ instantiates the difference description, as shown for *as you go south* in (53).

$$(53) \quad \llbracket \text{as you go south} \rrbracket = \lambda \alpha. \forall l, l' \in L_{n \rightarrow s} : l < l' \rightarrow \alpha([l, l'])$$

The modifier *as you go south* determines a spatial vector $L_{n \rightarrow s}$ going from a contextually given starting point southwards, and quantifies over pairs of subintervals of this vector. As shown by the derivation in (54), this makes a sentence like (52a) true iff any subinterval of the vector $L_{n \rightarrow s}$ instantiates a lengthening of cones.

$$(54) \quad \begin{aligned} \llbracket \text{as you go south}(\text{lengthen}(\text{the cones})) \rrbracket = \\ \lambda \alpha. \forall l, l' \in L_{n \rightarrow s} : l < l' \rightarrow \alpha([l, l']) (\lambda l_{\sigma}. f(\text{init}_l) <_{\text{length}} f(\text{end}_l)) = \\ \forall l, l' \in L_{n \rightarrow s} : l < l' \rightarrow f(\text{init}_{[l, l']}) <_{\text{length}} f(\text{end}_{[l, l']}) \end{aligned}$$

As is, this meaning is too strong. The sentence allows that there are intervals that do not exhibit cone lengthening. We need to take recourse to a contextually accessed threshold that would determine the relevant subset of subintervals as those that exceed it. We leave exploration of this issue for future research, noting only that the complication it introduces is general, not engendered particularly by our analysis of degree achievements.

4 Conclusion

We have argued above that a broader range of data associated with degree achievements and directed motion verbs motivates the move to a generalized analysis of the lexical semantics of these verbs that invokes individual concepts and ordered domains. The notion of temporal change, around which the analysis has been standardly built in the previous literature on the topic, is generalized to a notion of difference in the value of a function at initial and final subintervals over an ordered

domain. Not only the observed facts of degree achievements and directed motion verbs, but also the domain neutrality of a range of modifiers lends support to this generalized analysis. Future work should examine the extent to which this analysis is motivated for change of state verbs more generally, or whether it is restricted to the classes of verbs we have examined here.

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Ashwini Deo
Department of Linguistics
Yale University
370 Temple Street
New Haven, CT 06511, USA
ashwini.deo@yale.edu

Itamar Francez
Department of Linguistics
University of Chicago
1010 E 59th Street
Chicago, IL 60637, USA
ifrancez@uchicago.edu

Andrew Koontz-Garboden
Department of Linguistics & English Language
University of Manchester
Oxford Road
Manchester, M13 9PL, UK
andrewkg@manchester.ac.uk