How verbs of change target properties for change

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1 Introduction

Intuitively, there is a difference between the following two examples with respect to what is affected:

(1) a. Rebecca ate an apple (in five minutes).
    b. Rebecca peeled an apple (in five minutes).

In (1a), Rebecca ate the whole apple, whereas in (1b), she peeled only its skin.

Krifka (1992, p. 45) recognizes that an example like (1b) poses a problem for a particular mapping property, namely, mapping to events,[1] that he assumes in his aspectual theory:

> However, there are some problems with the mapping properties. With mapping to events, it is often the case that only a certain class of parts of the object are relevant. As an example, consider *eat the apple* and *peel the apple*; in the first case, all the parts of the apple are involved, whereas in the second case, only the surface parts are. Another example is *read the book* and *burn the book*; surely, there are parts of the book which are relevant in the second case (e.g., the cover of the book) which do not count as parts of the book in the first case. To handle these phenomena, we

[1]Krifka's definition of mapping to events is as follows (cf. p. 39, (P30)):

1. $\forall R(\mathbf{MAP\text{-}E}(R) \leftrightarrow \forall e \forall x \forall x'(R(x)(e) \wedge x' \sqsubseteq x \rightarrow \exists e'(e' \sqsubseteq \wedge R(x')(e'))))$

In prose, R (a relation between objects and events) satisfies mapping to events just in case if R applies to e and x, every part x' of x is related by R to a part e' of e.

may assume that the verb selects specific *aspects* of an object (e.g., only its surface).

To my knowledge, Krifka has never developed this idea further, and nor has anyone else in a Krifka-style framework.[2]

Notice that, strictly speaking, (1a) also poses a problem for mapping to events, because Rebecca (like most people) did not literally eat the whole apple: there were parts of the apple (around and including its core) that were not affected.

2 Aspects

How to model an *aspect* (to use Krifka's term) of an object? One way is to consider a particular aspect of an object as the value of a particular function (of logical type $\langle e, e \rangle$) when applied to the object. The two functions relevant in (1) are:

(2) a. $\mathbf{skin\text{-}of}(x)$ 'the skin of x'
b. $\mathbf{edible\text{-}part\text{-}of}(x)$ 'the edible part of x'

As a first approximation, the verbs in (1) receive the following analyses (ignoring tense), where the agent argument is expressed by the thematic relation **agent**:

(3) a. peel- $\rightsquigarrow \lambda y \lambda x \lambda e.\mathbf{peel}(\mathbf{skin\text{-}of}(y))(e) \wedge \mathbf{agent}(x)(e)$ (first version)
b. eat- $\rightsquigarrow \lambda y \lambda x \lambda e.\mathbf{eat}(\mathbf{edible\text{-}part\text{-}of}(y))(e) \wedge \mathbf{agent}(x)(e)$ (first version)

The two noun phrases in (1) are treated as follows:

(4) a. an apple $\rightsquigarrow \lambda R \lambda e.\exists x(R(x)(e) \wedge \mathbf{apple}(x))$
b. Rebecca $\rightsquigarrow$ **rebecca**

Finally, the analysis of (1b) (assuming quantifier raising of the object noun phrase) as an event predicate is as follows:

(5) an apple $[L_y$ Rebecca peel- $t_y] \rightsquigarrow$

$$[\lambda R \lambda e.\exists x(R(x)(e) \wedge \mathbf{apple}(x))](\lambda y \lambda e'.\mathbf{peel}(\mathbf{skin\text{-}of}(y))(e') \wedge \mathbf{agent}(\mathbf{rebecca})(e')) = \text{(by conversion)}$$

$$\lambda e.\exists x(\mathbf{peel}(\mathbf{skin\text{-}of}(x))(e) \wedge \mathbf{agent}(\mathbf{rebecca})(e) \wedge \mathbf{apple}(x))$$

The treatment of (1a) is analogous:

(6) an apple $[L_y$ Rebecca eat- $t_y] \rightsquigarrow$

$$\lambda e.\exists x(\mathbf{eat}(\mathbf{edible\text{-}part\text{-}of}(x))(e) \wedge \mathbf{agent}(\mathbf{rebecca})(e) \wedge \mathbf{apple}(x))$$

[2]Though the problem has sometimes been (re)mentioned, e.g., in Naumann (1995, chap. 3.3.1).

The analyses in (5) and (6) offer a reasonable way (for the verbs in question) of addressing the problem with mapping to events that Krifka points out, because now the "objects" (a.k.a. aspects) which are mapped to events are the skin of the apple and the edible part of the apple, respectively. At the same time, these analyses still have a significant shortcoming, one that in fact affects Krifka's account more generally.

3 Targeting properties for change

It seems correct to say that the meaning of (1a) entails that the apple existed at the beginning of the eating event and that it did not exist at the end of the eating event, and that the meaning of (1b) entails that the skin of the apple was connected to the apple at the beginning of the peeling event and that it was apart from the apple at the end of the peeling event. However, the analyses in (6) and (5) together with Krifka-style mapping properties do not validate these entailments. To put it another way, these analyses together with Krifka-style mapping properties do not reveal what in fact changes in the events denoted.

There are two strategies that could be pursued at this point. The first would be to attempt to build more information into the semantic representations to allow the desired inferences to be drawn. Yet this strategy can easily lead to overly complex semantic representations that are difficult to revise in a modular fashion.

The second strategy would to try to construct *local axiomatic theories* of the kinds of events denoted by the verbs of interest. Such local theories are not only easier to revise in a modular fashion but they also allow for a cleaner separation of linguistic and ontological issues.

3.1 Case study, I: eating events

With (1a) in mind, the main question is how to treat the gradual disappearance of the apple. Notice that it is not sufficient to say that the apple exists at the beginning of the event and does not exist at the end of the event, because this leaves open what happens to the apple between the beginning and the end of the event. A more satisfactory solution would be to model the gradual disappearance of the apple directly. Also, instead of speaking of existence, I will speak of the apple's being *present* or not.

The *ontological domains* that I presuppose are the following:

(7) Objects: $x, y, z, \dots$
Events: $e, e', e'', \dots$
Times: $t, t', t'', \dots$
Degrees: $d, d', d'', \dots$ (real numbers in $[0,1]$)

For present purposes, there are two *distinguished predicates*, both functions of type $\langle e, \langle e, \langle e \rangle\rangle\rangle$:

(8) $\mathbf{eat}(x)(e)$ 'the degree to which x is eaten in e'
$\mathbf{present}(x)(t)$ 'the degree to which x is present at t'

The first group of *local axioms* concern the predicate **eat**:

(9) a. $\forall x \forall e \forall d \forall e' \forall d' (\mathbf{eat}(x)(e) = d \wedge \mathbf{eat}(x)(e') = d' \wedge e' \sqsubset e \rightarrow d' < d)$ (strict d-incrementality)
b. $\forall x \forall e \forall d (\mathbf{eat}(x)(e) = d \wedge 0 < d < 1 \rightarrow \exists y (y \sqsubset x \wedge \mathbf{eat}(y)(e) = 1))$ (calibration to 1)
c. $\forall x \forall e \forall d (\mathbf{eat}(x)(e) = d \wedge d > 0 \rightarrow \mathbf{eat}(x)(\mathbf{beg}(e)) = 0)$ (left boundary condition)

The axiom in (9a) states that if x is eaten in event e to degree d and in event e' to degree d' and e' is a proper part of e, then d' is less than d. The axiom in (9b) says that if x is eaten in e to a degree between 0 and 1, then there is a proper part of x that is eaten in e to degree 1. The next axiom, in (9c), requires that if x is eaten in e to a positive degree, x is eaten to degree 0 in the (instantaneous) beginning event of e.

The second group of axioms makes reference to both of the distinguished predicates:

(10) a. $\forall x \forall e (\mathbf{eat}(x)(e) = 1 \rightarrow \mathbf{present}(x)(\tau(\mathbf{beg}(e))) = 1)$ (left boundary condition)
b. $\forall x \forall e (\mathbf{eat}(x)(e) = 1 \rightarrow \mathbf{present}(x)(\tau(\mathbf{end}(e))) = 0)$ (right boundary condition)
c. $\forall x \forall e \forall e' \forall d (\mathbf{eat}(x)(e) = 1 \wedge \mathbf{eat}(x)(e') = d \wedge e' \sqsubset_{ini} e \rightarrow \mathbf{present}(x)(\tau(\mathbf{end}(e'))) = 1 - d)$ (gradual decrease in presence)

The axiom in (10a) says that if x is eaten in e to degree 1, then x is present to degree 1 at the time of the (instantaneous) beginning event of e. The next axiom, in (10b), requires x to be present to degree 0 at the time of the (instantaneous) ending event of e if x is eaten in e to degree 1. Finally, the third axiom, in (10c), states that if x is eaten in e to degree 1 and in e' to degree d and e' is a proper initial part of e, then x is present at the time of the (instantaneous) ending event of e' to degree $1 - d$.

The final group of axioms concerns the predicate **present**:

(11) a. $\forall x \forall t \forall d (\mathbf{present}(x)(t) = d \wedge 0 < d < 1 \rightarrow \exists y (y \sqsubset x \wedge \mathbf{present}(y)(t) = 1)$ (calibration to 1)
b. $\forall x \forall t \forall d (\mathbf{present}(x)(t) = d \wedge d < 1 \rightarrow \exists t' (t' < t \wedge \mathbf{present}(x)(t') = 1)$ (earlier full presence)

The axiom in (11a) states that if x is present at t to a degree between 0 and 1, then there is a proper part y of x such that y is present at t to degree 1. The axiom in (11b) says that if x is present at t to a degree less than 1 (allowing for 0), then there is an earlier time t' such that x is present at t' to degree 1.

Since **eat** is now a function that yields degrees, the representation of *eat* needs to be revised slightly (cf. (3b)):

(12) eat- $\rightsquigarrow \lambda y \lambda x \lambda e.\mathbf{eat}(\mathbf{edible\text{-}part\text{-}of}(y))(e) = 1 \wedge \mathbf{agent}(x)(e)$ (final version)

The event predicate for (1a) is then as follows (cf. (6)):

(13) an apple [L_y Rebecca eat- t_y] $\rightsquigarrow$
$\lambda e.\exists x(\mathbf{eat}(\mathbf{edible\text{-}part\text{-}of}(x))(e) = 1 \wedge \mathbf{agent}(\mathbf{rebecca})(e) \wedge \mathbf{apple}(x))$

Suppose that there is an event e_1 in the denotation of the predicate in (13). Then there is an object x_1 such that $\mathbf{eat}(\mathbf{edible\text{-}part\text{-}of}(x_1))(e_1) = 1$, $\mathbf{agent}(\mathbf{rebecca})(e_1)$, and $\mathbf{apple}(x_1)$ all hold. Then the following facts can also be shown to hold:

(14) a. $\mathbf{present}(\mathbf{edible\text{-}part\text{-}of}(x_1))(\tau(\mathbf{beg}(e_1))) = 1)$
b. $\mathbf{present}(\mathbf{edible\text{-}part\text{-}of}(x_1))(\tau(\mathbf{end}(e_1))) = 0)$
c. $\forall e'(\mathbf{eat}(\mathbf{edible\text{-}part\text{-}of}(x_1))(e') = 0.4 \wedge e' \sqsubset_{ini} e_1 \rightarrow$
$\mathbf{present}(\mathbf{edible\text{-}part\text{-}of}(x_1))(\tau(\mathbf{end}(e'))) = 0.6)$
d. $\forall e'(\mathbf{eat}(\mathbf{edible\text{-}part\text{-}of}(x_1))(e') = 0.4 \rightarrow$
$\exists y(y \sqsubset \mathbf{edible\text{-}part\text{-}of}(x_1) \wedge \mathbf{eat}(y)(e') = 1))$
e. $\forall e'(\mathbf{present}(\mathbf{edible\text{-}part\text{-}of}(x_1))(\tau(\mathbf{end}(e'))) = 0.6 \rightarrow$
$\exists y(y \sqsubset \mathbf{edible\text{-}part\text{-}of}(x_1) \wedge \mathbf{present}(y)(\tau(\mathbf{end}(e'))) = 1))$

The degree 0.4 in (14c) and (14d) is given as an illustration—any positive degree may be given instead (in the case of another degree, the degree 0.6 will naturally change). In sum, this local theory of eating events captures the gradual disappearance of the object that is eaten.

3.2 Case study, II: peeling events

Turning to (1b), the local theory is similar in overall structure to the one of eating events. Again, there are two distinguished predicates (also functions of type $\langle e, \langle e, \langle e \rangle\rangle\rangle$):

(15) $\mathbf{peel}(x)(y)(e)$ 'the degree to which x is peeled from y in e'
$\mathbf{apart}(x)(y)(t)$ 'the degree to which x is apart from y at t'

The first set of axioms is for the predicate **peel**:

(16) a. $\forall x \forall y \forall e \forall d \forall e' \forall d'(\mathbf{peel}(x)(y)(e) = d \wedge \mathbf{peel}(x)(y)(e') = d' \wedge e' \sqsubset e \rightarrow$
$d' < d)$ (strict d-incrementality)

b. $\forall x \forall y \forall e \forall d(\mathbf{peel}(x)(y)(e) = d \wedge 0 < d < 1 \rightarrow$
$\exists z(z \sqsubset x \wedge \mathbf{peel}(z)(y)(e) = 1))$ (calibration to 1)

c. $\forall x \forall y \forall e \forall d(\mathbf{peel}(x)(y)(e) = d \wedge d > 0 \rightarrow$
$\mathbf{peel}(x)(y)(\mathbf{beg}(e)) = 0)$ (left boundary condition)

The second group of axioms concerns both of the distinguished predicates:

(17) a. $\forall x \forall y \forall e(\mathbf{eat}(x)(y)(e) = 1 \rightarrow$
$\mathbf{apart}(x)(y)(\tau(\mathbf{beg}(e))) = 0)$ (left boundary condition)

b. $\forall x \forall y \forall e(\mathbf{peel}(x)(y)(e) = 1 \rightarrow$
$\mathbf{apart}(x)(y)(\tau(\mathbf{end}(e))) = 1)$ (right boundary condition)

c. $\forall x \forall y \forall e \forall e' \forall d(\mathbf{peel}(x)(y)(e) = 1 \wedge \mathbf{peel}(x)(y)(e') = d \wedge e' \sqsubset_{ini} e \rightarrow$
$\mathbf{apart}(x)(y)(\tau(\mathbf{end}(e'))) = d)$ (gradual increase in separation)

The third group of axioms is for the predicate **apart**:

(18) a. $\forall x \forall y \forall t \forall d(\mathbf{apart}(x)(y)(t) = d \wedge 0 < d < 1 \rightarrow$
$\exists z(z \sqsubset x \wedge \mathbf{apart}(z)(y)(t) = 1)$ (calibration to 1)

b. No analogue of (11b)!

Since **peel** is now a function with an additional object argument that yields degrees, the representation of *peel* needs to be revised (cf. (3b)):

(19) peel- $\rightsquigarrow \lambda y \lambda x \lambda e.\mathbf{peel}(\mathbf{skin\text{-}of}(y))(y)(e) \wedge \mathbf{agent}(x)(e)$ (final version)

The event predicate for (1b) is now as follows (cf. (5)):

(20) an apple [L_y Rebecca peel- t_y] $\rightsquigarrow$
$\lambda e.\exists x(\mathbf{peel}(\mathbf{skin\text{-}of}(x))(x)(e) \wedge \mathbf{agent}(\mathbf{rebecca})(e) \wedge \mathbf{apple}(x))$

Results analogous to (14) hold for any event in the denotation of the predicate in (20).

3.3 Case study, III: mending events

Consider the following example:

(21) Rebecca mended the torn pants (in an hour).

In this case, the adjective *torn* explicitly signals the property that is changed.

As before, there are two distinguished predicates (again, functions of type $\langle e, \langle e, \langle e \rangle \rangle \rangle$):

(22) $\mathbf{mend}(x)(e)$ 'the degree to which x is mended in e'
$\mathbf{torn}(x)(t)$ 'the degree to which x is torn at t'

The first group of axioms concerns the predicate **mend**:

(23) a. $\forall x \forall e \forall d \forall e' \forall d'(\mathbf{mend}(x)(e) = d \wedge \mathbf{mend}(x)(e') = d' \wedge e' \sqsubset e \rightarrow$
$d' < d)$ (strict d-incrementality)

b. $\forall x \forall e \forall d(\mathbf{mend}(x)(e) = d \wedge 0 < d < 1 \rightarrow$
$\exists y(y \sqsubset x \wedge \mathbf{mend}(y)(e) = 1))$ (calibration to 1)

c. $\forall x \forall e \forall d(\mathbf{mend}(x)(e) = d \wedge d > 0 \rightarrow$
$\mathbf{mend}(x)(\mathbf{beg}(e)) = 0)$ (left boundary condition)

The second set of axioms pertains to both of the distinguished predicates:

(24) a. $\forall x \forall e(\mathbf{mend}(x)(e) = 1 \rightarrow$
$\mathbf{torn}(x)(\tau(\mathbf{beg}(e))) = 1)$ (left boundary condition)

b. $\forall x \forall e(\mathbf{mend}(x)(e) = 1 \rightarrow$
$\mathbf{torn}(x)(\tau(\mathbf{end}(e))) = 0)$ (right boundary condition)

c. $\forall x \forall e \forall e' \forall d(\mathbf{mend}(x)(e) = 1 \wedge \mathbf{mend}(x)(e') = d \wedge e' \sqsubset_{ini} e \rightarrow$
$\mathbf{torn}(x)(\tau(\mathbf{end}(e'))) = 1 - d)$ (gradual decrease in tornness)

The third group of axioms is for the predicate **torn**:

(25) a. $\forall x \forall t \forall d(\mathbf{torn}(x)(t) = d \wedge 0 < d < 1 \rightarrow$
$\exists y(y \sqsubset x \wedge \mathbf{torn}(y)(t) = 1))$ (calibration to 1)

b. Again, no analogue of (11b)!

The analysis of (21) is as follows:

(26) a. mend- $\rightsquigarrow \lambda y \lambda x \lambda e.\mathbf{mend}(\mathbf{torn\text{-}part\text{-}of}(y))(e) = 1 \wedge \mathbf{agent}(x)(e)$

b. the torn pants $\rightsquigarrow \iota x(\mathbf{pants}(x) \wedge \exists y(y \sqsubset x \wedge \mathbf{torn}(y)(t) = 1))$

c. Rebecca mend- the torn pants $\rightsquigarrow$
$\lambda e.\mathbf{mend}(\mathbf{torn\text{-}part\text{-}of}(\iota x($
$\mathbf{pants}(x) \wedge \exists y(y \sqsubset x \wedge \mathbf{torn}(y)(t) = 1))))(e) = 1 \wedge$
$\mathbf{agent}(\mathbf{rebecca})(e)$

Again, results analogous to (14) hold for any event in the denotation of the predicate in (26c).

4 Comparison with Pustejovsky (2000)

(I still have to add a comparison with Pustejovsky's approach.)

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