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Tense, aspect and temporal order: *before* and *after*

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by

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REPORT

Presented to the Faculty of the Graduate School of
The University of Texas at Austin
in Partial Fulfillment
of the Requirements
for the Degree of

MASTER OF ARTS

THE UNIVERSITY OF TEXAS AT AUSTIN
May 2014

To Catherine, who loved Henry before he loved her,
and to Henry, who loved Catherine after she loved him.

Acknowledgments

It is impossible to overstate the intellectual and personal debt I owe to my supervisors, David Beaver and Hans Kamp. Both have shown great kindness, patience and generosity and have provided precisely the right mixture of criticism and encouragement just when both were most needed. I'm also grateful for conversations with too many linguists and philosophers to name, but I want to mention in particular Jason Baldridge, Colin Bannard, John Beavers, Gemma Boleda, Cleo Condoravdi, Ashwini Deo, Josh Dever, Katrin Erk, Kai von Fintel and Steve Wechsler.

Special thanks to the friends I've made while at the University of Texas. Many have helped me with research in very direct ways, and all of them have helped to make my time here more enjoyable than I could have hoped: Derek Anderson, Amila Becirbegovic, Daniel Boyd, Chris Brown, Travis Brown, Dylan Bumford, Cindy Chung, Liz Coppock, John Davidson, Emilie Destruel, Ryan Dux, Joey Frazee, Ashwini Ganeshan, Derya Kadipasaoglu, Jörn Klinger, Meredith Lehman, Sandra Markarian, Kate Ritchie, Carson Sandy, Anders Schoubye, Annie Steele, Tammi Stout, Lauren Terzenbach, Leah Velleman and Casey Woolwine.

I'd also like to take this opportunity to acknowledge my many friends and teachers from earlier stages in my life, all of whom have had an important

impact on my academic and personal development: Fred Aquino, Richard Beck, Austin Faulkner, Philip Goode, Josh Harris, Randy Harris, Conrad Hester, Adam McDonough, Nate Monroe, Paul Morris, Amy Parnell, Nancy Shankle, Leah Sloan, Patricia Snow, Henry Speck and Alex Vess. Finally, I'd like to thank my family: my grandparents, my parents, Joey and Nancy, my brother, Jeremy, and my niece, Bella. I love all of you beyond words.

I couldn't have completed this report without the support of everyone mentioned above (and many more whom I've undoubtedly forgotten and to whom I offer my sincere apologies). It goes without saying that the deficiencies in what follows (of which there are many) are solely my responsibility.

Tense, aspect and temporal order: *before* and *after*

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Anscombe (1964) presents influential arguments that *before* and *after* cannot denote converse relations, despite intuitions to the contrary. These arguments, I claim, rely on ambiguity of certain *before*- and *after*-sentences, ambiguity that arises from the interaction of tense and aspect with the temporal ordering relations denoted by *before* and *after*. To account for this ambiguity, I adopt a Discourse Representation Theory-based analysis of tense and aspect (Kamp & Reyle 2011) and apply it to a set of examples that exhibit the variety of readings available for *before*- and *after*-sentences. I argue that certain readings of stative *after*-sentences support the existence of an inceptive coercion operator, equivalent in effect to the aspectual verb *begin*. This operator has much in common with *earliest*, an operator proposed by Beaver & Condoravdi (2003b), but it is motivated by independent aspectual considerations. I conclude with a discussion of areas for future research.

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Chapter 1

Introduction

English speakers typically judge pairs of sentences like those in (1) to be mutually entailing, lending support to the claim, noted by Anscombe (1964: 3), that "[nothing] is more natural than to suppose that *before* and *after*, in their temporal sense, name converse relations."

(1) a. Catherine kissed Henry before she left.
    b. Catherine left after she kissed Henry.

What does it mean to claim that *before* and *after* name converse relations? In section 1.1, I make this claim precise by providing relevant definitions in a typed first-order logic. In section 1.2, I present a well-known puzzle that poses a problem for the converse analysis, and in sections 1.3 and 1.4, I consider two previous approaches to this problem. Finally, in section 1.5, I present an alternative approach to the problem involving an independently motivated theory of tense and aspect. The remainder of the report develops the theory formally, adopting tools from minimalist syntax (Chomsky 1995) and from Discourse Representation Theory (Kamp 1981), and concludes by considering prospects for addressing a wider variety of tense and aspect phenomenon within the general framework.

1.1 Definitions

In order to make precise claims about the semantics of *before* and *after*, we must characterize a class of models that include not only individuals but also times and eventualities.[1] Further, the domains of times and eventualities must be structured by certain primitive relations. First, let's define a time structure (cf. Landman 1991, Kamp & Reyle 1993):

(2) Let $\langle \mathrm{I}, < \rangle$ be a time structure where:

a. 'I' is a set of *instants*, equivalent to the set of real numbers.

b. '<' is a strict total order over I with the following properties:

(i) $\forall x, y \in \mathrm{I}\,[(x < y) \rightarrow (x \neq y)]$ (irreflexivity)

(ii) $\forall x, y \in \mathrm{I}\,[(x < y) \vee (y < x) \vee (x = y)]$ (connectedness)

(iii) $\forall x, y, z \in \mathrm{I}\,[((x < y) \wedge (y < z)) \rightarrow (x < z)]$ (transitivity)

From $\langle \mathrm{I}, < \rangle$, we may define an interval structure:

(3) Let $\langle \mathbb{I}, \prec, \sqsubseteq \rangle$ be an interval structure, where:

a. $\mathbb{I}$ is the set of all convex subsets of I:

$$\{i \subseteq \mathrm{I} \;:\; \forall x, y, z \in \mathrm{I}\,[(x \in i \wedge z \in i) \rightarrow (x \leq y \leq z \rightarrow y \in i)]\}$$

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[1] I follow Bach (1981) in adopting the term *eventuality* as a general, technical term covering *events*, *states* and any other similar entities that we admit to our ontology.

b. '$\prec$' is a strict partial order over $\mathbb{I}$, such that:

$$\forall x', y' \in \mathbb{I}\,[x' \prec y' \leftrightarrow \forall x \in x', y \in y'\,[x < y]]$$

c. '$\sqsubseteq$' is a total order over $\mathbb{I}$, such that:

$$\forall x', y' \in \mathbb{I}, x \in x'\,[x' \sqsubseteq y' \rightarrow x \in y']$$

Next, let's define *binary converse relations* R and R' as in (4). (See Causey 2001: 134 for an equivalent definition.)

(4) R and R' are converse relations *iff* $\forall x, y\,[R(x, y) \leftrightarrow R'(y, x)]$

a. Let $\succ$ be the converse of $\prec$: $\forall x, y \in \mathbb{I}\,[x \prec y \leftrightarrow y \succ x]$

b. Let $\sqsupseteq$ be the converse of $\sqsubseteq$: $\forall x, y \in \mathbb{I}\,[x \sqsubseteq y \leftrightarrow y \sqsupseteq x]$

Finally, let's define a class of models $\mathcal{M}$:

(5) $\mathcal{M} = \{\mathrm{M} \ : \ \mathrm{M} = \langle \langle \mathbb{A}, \mathrm{Name} \rangle, \langle \mathbb{E}, \langle \mathbb{I}, \prec, \sqsubseteq \rangle, T \rangle, \mathrm{Predicate} \rangle\}$, where:

a. $\mathbb{A}$ is a set of individuals.

b. *Name* is a function from names to elements of $\mathbb{A}$.

c. $\mathbb{E}$ is a set of eventualities.

d. T is a function from $\mathbb{E}$ to $\mathbb{I}$.

e. *Predicate* is a function from predicates to sets of tuples over $\mathbb{A}, \mathbb{E}, \mathbb{I}$.

The relation T captures the fact that eventualities like Catherine's kiss and her departure are anchored at intervals of time.[2]

Given these definitions we might spell out the intuition that *before* and *after* denote converse relations with the following semantic analysis, in a typed lambda-calculus where x and y vary over intervals:

(6) a. *before* $\mapsto \lambda y.\ \lambda x.\ x \prec y$

b. *after* $\mapsto \lambda y.\ \lambda x.\ x \succ y$

On this analysis, (1a) is true *if and only if* (1b) is true; each is satisfied in all and only models wherein the interval of the kiss precedes the interval of the departure. For example, the informal model in figure 1.1 satisfies both (1a) and (1b), where lines represent the intervals of time corresponding to the eventualities given by the object language labels and where the temporal relation $\prec$ is represented by the spatial relation *entirely left of.* This formalization fits nicely with intuitions concerning the mutual entailment between the items in (1).

1.2 A temporal-inference puzzle

Unfortunately, matters are not so straightforward. Certain pairs of sentences with forms ostensibly identical to those of the pair in (1) fail to

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[2] Perhaps at least some eventualities map to *instants.* Note that this is not ruled out by the relation T; by defining $\mathbb{I}$ as the set of convex subsets of I, we guarantee that for all $x \in \mathrm{I}$, $\{x\} \in \mathbb{I}$.

Figure 1.1 A model satisfying (1a) and (1b)

exhibit the mutual entailment relation observed above.

(7) a. Catherine loved Henry before he loved her.
b. Henry loved Catherine after she loved him.

Now, the pair in (7) *could* be interpreted like the pair in (1), such that the interval wherein Catherine loved Henry is understood to precede entirely the interval wherein he loved her. Yet this is not the only possible interpretation, nor is it the most natural in many contexts. Consider the informal model in figure 1.2, which, intuitively, satisfies (7b) but not (7a); in this model, Henry loved Catherine *before and after* she loved him. Such considerations cast doubt on the supposition that *before* and *after* denote converse relations.

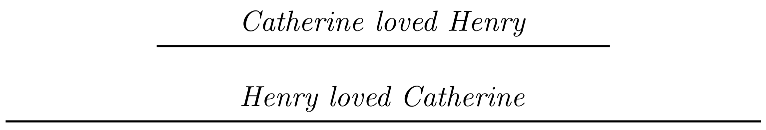

Figure 1.2 A model that intuitively satisfies (7b) but not (7a)

1.3 The quantificational analysis

In light of similar considerations, Anscombe (1964) considers a quantificational analysis of *before*- and *after*-sentences (later adopted in Higginbotham 1988, Landman 1991, and elsewhere) along the lines in (8), where A and B denote intervals and t, t' vary over instants.[3]

(8) a. A *before* B *iff* $\exists t \in A\,[\forall t' \in B\,[t < t']]$

b. A *after* B *iff* $\exists t \in A\,[\exists t' \in B\,[t > t']]$

On the analysis in (8), the model in figure 1.2 satisfies (7b) (because there is a point t in the interval of Henry's love for Catherine that follows a point t' in the interval of Catherine's love for Henry) and falsifies (7a) (because there is no point t in the interval of Catherine's love for Henry that precedes all points t' in the interval of Henry's love for Catherine). In other words, the predictions made by (8) correspond to the intuition noted above — a speaker committed to (7b) need not commit to (7a). In fact, our speaker may remain completely agnostic with respect to the question of who loved whom first. However,

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[3] The definitions given here are similar to those given by del Prete (2006) in his discussion of Anscombe's discussion of the quantificational analysis, the main difference being that his definitions (following Anscombe's informal remarks) are cast not in terms of intervals but rather in terms of propositions.

Hans Kamp (*personal communication*) has pointed out that the definition given for *after* here is *extremely* weak: on this definition, A *after* A will always be true for any non-instantaneous interval A. However, this *does* seem to be the definition implied by Anscombe (1964: 10), modulo the exchange of propositions for intervals: " 'p after q' means: 'a time at which p was after a time at which q.' "

See del Prete 2006 for careful exegesis and discussion of Anscombe's article. It should be noted that Anscombe herself rejects the quantificational analysis.

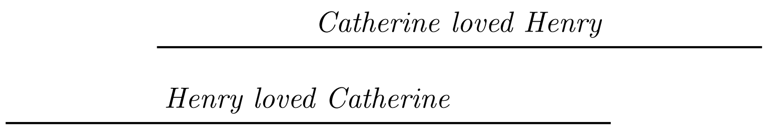

Figure 1.3 Another model that satisfies (7b) but not (7a), given (8)

while the analysis is compatible with the judgments concerning the pair in (7) with respect to the model in figure 1.2, it makes a variety of questionable predictions.

First, consider the model in figure 1.3. Note that this model also satisfies (7b) and falsifies (7a) on the analysis in (8), by the same reasoning as that given with respect to figure 1.2. So not only does the analysis in (8) predict the fact, previously noted, that a speaker committed to (7b) need not have any commitments concerning who loved whom earliest — but it goes further and predicts that the speaker need not commit to any claim concerning who loved whom latest. Yet arguably, the stronger interpretation is more natural in (7b) — as well as in (9) from Beaver & Condoravdi 2003b: 45.

(9) Harrison was alive after Lennon was alive.

Indeed, (9) might felicitously answer the question of who outlived Lennon, in which case it is understood that there is a time at which Harrison was alive following *all* times at which Lennon was alive. So the interpretation of *after*

Figure 1.4 A model that satisfies (1b) but not (1a), given (8).

is often stronger than that given by the analysis in (8). The possibility of this stronger interpretation requires an explanation.

Next, recall the mutual entailment observed for the pair in (1) and consider whether the quantificational analysis provides an explanation for the intuitions discussed above. The model in figure 1.4, where Catherine's departure includes her kiss, should falsify (1a) and satisfy (1b) on the analysis in (8), contrary to intuitions.[4]

Finally, we consider a theoretical objection: on the quantificational analysis, the converse ordering relations '$<$' and '$>$' are employed, but *before* and *after* cannot denote these relations directly, since the logical forms given in (8) are non-uniform — somehow *before* introduces universal quantification while *after* introduces existential quantification. An alternative explanation for the linguistic facts that avoided this non-uniformity would be preferred on

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[4] Of course, this model is only possible on the assumption that the eventualities involved may correspond to extended intervals. Instead, one might claim that these eventualities must map to instants. There is indeed a linguistic argument in favor of this view. Yet this argument raises the further question of why certain clauses or clause types necessarily correspond to instants while others are free from this restriction — especially given the common sense view that eventualities are extended in time. In any case, the facts concerning (1) do not follow from the analysis in (8) without additional argument.

grounds of theoretical elegance, *ceteris paribus*.

1.4 A converse analysis with temporal coercion

Beaver & Condoravdi (2003a,b) offer just such an alternative analysis, preserving the intuition of converseness. In Beaver & Condoravdi's (2003a) fragment, *before* and *after* denote the relations '$<$' and '$>$' directly, relations that take instants as arguments (consistent with the definitions in section 1.1). They propose the truth-conditions in (10) for *before*- and *after*-sentences, still letting A and B denote intervals and letting t vary over instants.

(10) a. A *before* B *iff* $\exists t \in A\,[t < \text{earliest}(B)]$

b. A *after* B *iff* $\exists t \in A\,[t > \text{earliest}(B)]$

These truth-conditions feature a novel coercion operator, *earliest*, which maps the interval denoted by B to a particular instant — B's initial bound. Note that existential quantifaction over A is assumed to be a consequence of tense.

On this analysis (7b) is satisfied by the model in figure 1.2 because there is an instant of time in the interval wherein Henry loved Catherine strictly subsequent to the earliest instant of time in the interval wherein Catherine loved Henry, while (7a) is falsified in this model because there is no instant of time in the interval wherein Catherine loved Henry strictly preceding the earliest instant of time wherein Henry loved Catherine. Similarly, the model in figure 1.3 satisfies (7b) and falsifies (7a) on the analysis in (10).

These predictions are identical to those made by the quantificational analysis in (8): both accounts essentially adopt a weak semantics for *after*. Accordingly, Beaver & Condoravdi's analysis inherits the issues raised previously in connection with the quantificational analysis. It requires an explanation, first, for the possibility of a strong interpretation of *after* in (7b) and (9)[5], and second, for the intuition that (1a) and (1b) are mutually entailing.

1.5 A converse analysis with aspectual coercion

Consider again the core data in (1) and (7), repeated as (11) and (12).

(11) a. Catherine kissed Henry before she left.
  b. Catherine left after she kissed Henry.

(12) a. Catherine loved Henry before he loved her.
  b. Henry loved Catherine after he loved her.

In this report, I claim that the intuitions concerning the interpretations and inferences associated with (11) and (12), can be captured by adopting a small number of reasonable positions concerning the semantics of *tense*, *aspect* and

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[5] Beaver & Condoravdi suggest that coercion operators aside from *earliest* may be selected on pragmatic grounds, and this suggestion is elaborated in subsequent work (Beaver 2004, 2008), where *before* and *after* are reanalyzed as relations over intervals (consistent with the definitions of $\prec$ and $\succ$ given in section 1.1), with coercion responsible for selecting between weak and strong readings. The analysis I discuss in the following section takes its inspiration from these developments, but as shall be seen, it differs in its choice of coercion operators — instead of pure temporal operators, it draws on independently motivated aspectual operators.

temporal modification. The proposal I develop below preserves the intuition of converseness, but it also provides for the strong readings illustrated by (12b) and (9) and it predicts the mutual entailment in (11).

I will use the remainder of this introduction to sketch the "reasonable positions" mentioned above and indicate in broad strokes the role they play in the derivation of a few key examples:

(13) Adopting Kamp & Reyle's (1993) *Discourse Representation Theory*, our representation language provides constants for *eventualities* of at least two types — *events* and *states* (corresponding to elements of $\mathbb{E}$ in the class of models defined in (5)). Additionally, it includes the following operators:

a. *before* and *after*, corresponding to $\prec$ and $\succ$, respectively.
b. *in* and *includes*, corresponding to $\sqsubseteq$ and $\sqsupseteq$, respectively.
c. *time*, which assigns an *eventuality time* to each eventuality, and
d. *result*, which assigns a result state to each event, or conversely, *incep*, which assigns an inceptive event to each state.

(14) Contra Reichenbach 1947 and Kamp & Reyle 1993, where *tense* introduces a *reference time* to mediate between *eventuality time* and *utterance time*, I argue that reference times are optional arguments of eventualities and that they are only introduced by overt expressions

of temporal modification.[6]

(15) The *eventuality type* of an eventuality determines the relation between its eventuality time and the reference time introduced by a temporal modifier (cf. Kamp & Reyle 1993, 2011). Letting e and s represent arbitrary events and states, respectively, and letting t represent an arbitrary reference time, we adopt the following constraints:

a. The event-time constraint: $t : \mathrm{include}(\mathrm{time}(e))$

b. The state-time constraint: $t : \mathrm{in}(\mathrm{time}(s))$[7]

(16) Tense morphology in *before*- and *after*-clauses is semantically vacuous; i.e., *before*- and *after*-clauses do not introduce independent tense; rather, they exhibit *tense agreement.* (See sections 2.3, 4.2 and 4.3.1.)

Adopting these claims, I return to the examples introduced above.

The major contrast between (11) and (12) involves the semantic types of the eventualities introduced by their verbs.[8] In (11), *kiss* and *leave* introduce *events.* Let e_{kiss} represent the eventuality time of Catherine's kiss, let e_{leave} represent the eventuality time of Catherine's departure, let r_{kiss} represent the

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[6] Here and below, I often use the term *time* for consistency with prior literature; assume that *time* means *interval* unless otherwise indicated.

[7] In Kamp & Reyle 1993, the relation between state times and reference times is mere *overlap*, while the relation given here is adopted from Kamp & Reyle 2011. Of course, Kamp & Reyle assume that reference times are introduced by the tenses, not by adverbials.

[8] The assignment of verbs to eventuality types relies on the application of standard diagnostics further discussed in sections 4.1 and 5.2. For expository purposes, I simply take the eventuality type of the referents introduced by these verbs as given for now.

reference time introduced by the temporal modifier in (11a) and similarly, let r_{leave} represent the reference time introduced in (11b). The relation between e_{kiss} and e_{leave} in (11a) is derived in (17).

(17) a. $e_{\text{kiss}} \sqsubseteq r_{\text{kiss}}$ (from (11a) by principle (15a))
b. $r_{\text{kiss}} \prec e_{\text{leave}}$ (from (11a) by definition (6a))
c. $e_{\text{kiss}} \prec e_{\text{leave}}$ (from (17a) and (17b) by definitions (3c) and (3b))

Similarly, the relation between e_{kiss} and e_{leave} in (11b) is derived in (18).

(18) a. $e_{\text{leave}} \sqsubseteq r_{\text{leave}}$ (from (11b) by principle (15a))
b. $r_{\text{leave}} \succ e_{\text{kiss}}$ (from (11b) by definition (6b))
c. $e_{\text{leave}} \succ e_{\text{kiss}}$ (from (18a) and (18b) by definitions (3c) and (4a))

These analyses lead to equivalent results (capturing the observed mutual entailment) and eliminate the possibility of overlap.

In (12), on the other hand, the tokens of *love* introduce states. Let $s_{\text{Catherine}}$ represent the eventuality time of Catherine's love for Henry, let s_{Henry} represent the eventuality time of Henry's love for Catherine, let $r_{\text{Catherine}}$ represent the reference time introduced by the temporal modifier in (12a) and similarly, let r_{Henry} represent the reference time introduced in (12b). Consider the following facts:

(19) a. $s_{\text{Catherine}} \sqsupseteq r_{\text{Catherine}}$ (from (12a) by (15b))
b. $r_{\text{Catherine}} \prec s_{\text{Henry}}$ (from (12a) by (6a))

Crucially, these facts don't license the inference that $s_{\text{Catherine}} \prec s_{\text{Henry}}$ since we are only assured that a *subinterval* of $s_{\text{Catherine}}$ precedes the interval s_{Henry}. Consequently, overlap between $s_{\text{Catherine}}$ and s_{Henry} is not ruled out. Similarly, the facts in (20) don't license the inference that $s_{\text{Henry}} \succ s_{\text{Catherine}}$.

(20) a. $s_{\text{Henry}} \sqsupseteq r_{\text{Henry}}$ (from (12b) by (15b))
b. $r_{\text{Henry}} \succ s_{\text{Catherine}}$ (from (12b) by (6b))

However, these facts do assure us that a *subinterval* of s_{Henry} follows the interval of $s_{\text{Catherine}}$. And fortunately, this the precisely what we need to capture the strong interpretation of (12b). Crucially, this is compatible with a model in which the eventuality time of Henry's love for Catherine properly includes the eventuality time of Catherine's love for Henry, as in figure 1.2. This type of analysis also provides the desired interpretation for (9).

How do the positions adopted above account for the judgment that the model in figure 1.3 might satisfy (12b), given appropriate context? Here, (13d) comes into play. Following Moens & Steedman (1988), I adopt an *aspectual* coercion operator *result*, mapping events to result states.[9] Given that our models must already provide a mapping from events to their result states,

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[9] Moens & Steedman provide a highly articulated theory of aspectual coercion modeled as a network of eventuality types related by type-shifting operators. As suggested by (13), I assume only two types of eventualities — *events* and *states* — for the moment. In section 5.2, I will consider some reasons for subdividing events into *culminations*, *processes*, *culminated processes* and *points*, in Moens & Steedman's terminology. In the interim, all of my "events" correspond to Moens & Steedman's *culminations* (also called *achievements*, e.g., in Vendler 1957, Dowty 1979, Smith 1997).

the converse mapping from states to their inceptive events comes at no extra theoretical cost. Moreover, as I argue below, just such a mapping is *overtly* triggered by the aspectual verb *begin.* So (21) provides a natural paraphrase for the relevant interpretation of (12b), which is satisfied by the model in figure 1.3.

(21) Henry loved Catherine after she began to love him.

In light of these facts, the claim that — *in certain contexts* — inceptive interpretations are available even in the absence of an overt trigger follows naturally. As the mention of *contexts* suggests, I take covert inceptive coercion to be triggered pragmatically; consequently, I'm obliged to describe just how it is that a context can trigger aspectual coercion, a task which I leave for future work.

We are now in a position to account for the judgement that the model in figure 1.3 might satisfy (12b). The derivation in (22) illustrates inceptive coercion.

(22) a. $s_{\text{Henry}} \sqsupseteq r_{\text{Henry}}$ (from (12b) by (15b))

b. $r_{\text{Henry}} \succ \text{incep}(s_{\text{Catherine}})$ (from (12b) by (6b))

The facts in (22) assure us that there is a subinterval of Henry's love for Catherine that follows the inception of Catherine's love for Henry. Consequently, the model in figure 1.3 satisfies the interpretation of (12b) derived here, as desired.

The proposal I have outlined here has much in common with the approach taken by Beaver & Condoravdi. We both treat *before* and *after* as converse relations. Here (as in Beaver 2004, 2008) they are analyzed as relations over *intervals*, and consequently, coercion is not a *semantic requirement* but is rather a *pragmatic option.* My account departs from that of Beaver & Condoravdi in locating the coercion operators within the aspectual system.

1.6 The central tasks of this report

The central tasks of the remainder of this report will be to spell out my proposal within a formal, compositional framework and to justify the claims in (13) through (16). The next two chapters develop the framework. In chapter 2, I introduce a simple, minimalist architecture including a lexicon and a syntactic operation *merge*, and I derive logical forms for our core data. In chapter 3, I introduce *Discourse Representation Theory* or *DRT* (Kamp 1981, Kamp & Reyle 1993, 2011); in particular, I provide a compositional construction algorithm that maps logical forms to *Discourse Representation Structures* or *DRSs* — formulae of the *DRS-language.*

Chapter 4 is the heart of the report. It addresses the semantics of *tense* and *temporal modifiers* with special attention to *before* and *after.* The analysis I provide here allows us to derive representations consistent with the strong interpretations of our core data. Meanwhile, the discussion also motivates the distinction between *events* and *states.* In section 4.3, I derive weak interpretations of our *after*-data by introducing an inceptive operator, adopting insights from Moens & Steedman 1988 *inter alia*.

In chapter 5, I discuss additional empirical puzzles that may require revision of the theory of *before* and *after* developed here. I also discuss several unresolved issues (theoretical and empirical) in the syntax and semantics of tense, aspect and temporal modification.

Chapter 2

Syntactic preliminaries

Now I adopt a minimalist grammar for a small fragment of English, where a *grammar* is understood to be a computational system that defines a set of sign-meaning pairs. Since our concerns are primarily semantic, I will only focus on the components of the grammar required for the derivation of *logical forms* — representations interpretable by an independent conceptual-intentional system, i.e., I will largely ignore important questions concerning the derivation of *phonological forms* interpretable by an articulatory-perceptual system. Given this restriction, our grammar must minimally include a lexicon and constituent building operations. I discuss each of these grammar components in turn.

2.1 The lexicon $\mathcal{L}$ and feature sets

In the computational system developed here, a lexicon $\mathcal{L}$ is an *object* (in the technical sense familiar from the *object-oriented programming paradigm*). Its attributes and methods will be further elaborated in section 3.2. For the moment, I define only the attribute $\mathfrak{l}$ whose value is a set of lexical items. A tentative value for $\mathfrak{l}$ is illustrated by figure 2.1. Several comments are required.

$$\mathfrak{l} = \left\{ \begin{array}{ll} \{\text{A, Catherine}\}, & \{\text{A, Henry}\}, \\ \{\text{T, before}\}, & \{\text{T, after}\} \\ \{\text{T, kiss-present}\}, & \{\text{T, kiss-past}\}, \\ \{\text{T, leave-present}\}, & \{\text{T, leave-past}\}, \\ \{\text{T, love-present}\}, & \{\text{T, love-past}\} \end{array} \right\}$$

Figure 2.1 Lexical Items

First, lexical items are feature sets (cf. Chomsky 1995). That is to say that lexical items are not actually theoretical primitives; rather, they are *sets* of features. (Accordingly, I use set-theoretic notation in figure 2.1 instead of standard brackets.) The true theoretical primitives in figure 2.1 are category features (represented by single capital letters) and identity features (which look suspiciously like English words).

Let's first consider the category features: A and T. These categories are not the standard syntactic categories of the generative tradition. We will not adopt phrase structure rules sensitive to category features, nor will we formulate grammatical principles in terms of them. I adopt category features merely because they are suggestive of the semantics I will develop in chapters 3 and 4, which involve representations with typed-referential arguments. Roughly, the lexical items in figure 2.1 with the A feature will introduce *individuals* and those with the T feature will introduce *times*. In section 2.3, we will extend our inventory of types.

Now let's consider the identity features that we find in figure 2.1.

Though these features look like English words, this isn't necessary; any unique identifiers would do. In particular, I claim no connection between these features and the phonological representation of lexical items: as previously noted, issues of phonological representation are beyond the scope of this report.

2.2 The syntactic operation *merge*

The lexical items introduced above are *syntactic objects* of a rather simple sort — they are *sets* of primitive features. Of course, our grammar should also generate more complex syntactic objects, *phrases* or *constituents*. According to Hornstein et al. (2005: 201), building a phrase involves "combining diverse elements, labeling the resulting combination, and imposing a linear order on the elements so combined." I won't address any of the interesting and important questions concerning linear order in this report. The issue of labeling will arise briefly at the end of this section. For now, I focus on the mechanism for "combining diverse elements."

Let's adopt the operation *merge* as the basis for the construction of phrases. Following in part the *bare phrase structure* approach of Chomsky (1995), I assume that *merge* is a *set building operation* as defined in (23). Let α and β be syntactic objects.

(23) $\text{merge}(\alpha, \beta) = \{\alpha, \beta\}$

Crucially, we take both feature sets *and* sets output by *merge* to be *syntactic* *objects*. Thus *merge* may operate on its own output.[1]

Consider the application of *merge* to the simple syntactic objects (lexical items) corresponding to the expressions *Catherine* and *left* in (24).

(24) merge({A, Catherine}, {T, leave-past}) =
{ {A, Catherine}, {T, leave-past} }

Although it makes intuitive sense to merge the items in (24), we should ask: what prevents *merge* from applying to arbitrary syntactic objects, say {T, leave-past} and {T, kiss-present}? The answer is *nothing*; as defined, *merge* massively overgenerates linguistic structures. In chapters 3 and 4, we will rely on the selectional restrictions of semantic representations to constrain the output of our grammar.[2] This is why we can make do without a theory of constituent selection with category sensitive phrase structure rules. These are unnecessary in our syntax, given the semantics to come. Consequently, we have no need for the labeling operation attributed to *merge* by Hornstein et al.. Perhaps this would be an optimal design feature for grammars with broader coverage, but this issue is orthogonal to our concerns.

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[1] Though we are defining syntactic structures as sets, note that the definition of merge ensures that the structures we generate will always be isomorphic with tree structures with feature sets as terminal nodes. We will exploit this in the construction algorithm of section 3.4.

[2] The semantic interpretation function will map lexical items to pairs including not only the typed-referential arguments mentioned in section 2.1 but also including expressions of a type-theoretic lambda calculus — a language for composing Discourse Representation Structures (DRSs). The DRS composition process will be sensitive to the selectional restrictions that are expressible in this language.

Nevertheless, in the following sections, prior to the development of our semantic representation language, I will rely on our category features to guide intuitions about what sorts of syntactic structures it makes sense to generate through applications of *merge*. The reader should keep in mind that this is merely a stopgap.

2.3 Tense, temporal modifiers and agreement

In this section, we will consider two questions concerning temporal modifiers — specifically *before*- and *after*-modifiers: how are they structured, and when or where do they merge with main clause structures? In our attempt to analyze temporal modifiers, we will find that *tense agreement* phenomena present a challenge. I address this challenge by revising the set of lexical items in figure 2.1, forshadowing the compositional semantic analysis to be developed in the following chapters.

Let's begin by considering the internal structure of the phrase *after Catherine kissed Henry.* Assume that we first merge the feature structures corresponding to *kissed* and *Henry* and then we merge the resulting structure with the feature structure of *Catherine*:

(25) $\Big\{ \{\text{A, Catherine}\}, \Big\{ \{\text{T, kiss-past}\}, \{\text{A, Henry}\} \Big\} \Big\}$

What is the next step in the derivation? We might expect to merge the feature structure of *after* to the structure in (25) and then perhaps to merge the resulting structure with that in (24) as illustrated here:

(26)

$$?\left\{\begin{array}{l} \{\ \{\text{A, Catherine}\}, \{\text{T, leave-past}\}\ \}, \\ \quad \{\ \{\text{T, after}\}, \{\ \{\text{A, Catherine}\}, \{\ \{\text{T, kiss-past}\}, \{\text{A, Henry}\}\ \}\ \}\ \} \end{array}\right\}$$

However, there are empirical reasons to doubt that our core data correspond to structures like (26). Consider the unacceptable sentences in (27).

(27) a. *Catherine kissed Henry before she leaves.

b. *Catherine leaves after she kissed Henry.

These data illustrate the fact that our grammar requires *tense agreement* between tense morphology in main clauses and in *before*- and *after*- modifiers. Can we enforce this requirement syntactically? Not with our current resources. As previously discussed, the operation *merge* puts no restrictions on its arguments (so long as they are either feature sets or complex sets ultimately built from feature sets). Consequently, our syntax can freely generate structures like the following:

(28)

$$*\left\{\begin{array}{l} \{\ \{\text{A, Catherine}\}, \{\text{T, leave-present}\}\ \}, \\ \quad \{\ \{\text{T, after}\}, \{\ \{\text{A, Catherine}\}, \{\ \{\text{T, kiss-past}\}, \{\text{A, Henry}\}\ \}\ \}\ \} \end{array}\right\}$$

How can we prevent overgeneration of this sort?

Suppose we revise our inventory of lexical items. For example, instead of the pairs, $\{\text{T, kiss-present}\}$ and $\{\text{T, kiss-past}\}$ or $\{\text{T, love-present}\}$ and $\{\text{T, love-past}\}$, we adopt $\{\text{E, kiss}\}$ and $\{\text{S, love}\}$ as well as independent feature sets $\{\text{T, present}\}$ and $\{\text{T, past}\}$. Now the lexical items corresponding to *kiss* and *love* include no tense-specifying features, and their category features have changed, foreshadowing the semantics I will defend in chapter 4. Roughly, I argue (following Davidson 1967, Kamp & Reyle 1993) that the semantics of these expressions involves *events* and *states* as illustrated in table 2.1. This revision has important consequences for our theory of tense and temporal modification.

feature	type	description
A	a	individual
T	t	time
E	e	event
S	s	state

Table 2.1 Feature/Type associations

With respect to the tenses, we might now claim that their semantic representations encode selectional restrictions that requires the referential argument of an immediately adjoined structure to be of type e or s.[3] With respect to the internal structure of temporal modifiers, we might similarly claim that the semantic representations corresponding to *before* and *after* select for type e or s referential arguments. This suggests the structure in (29).

(29) $\Big\{ \{\text{T, after}\}, \Big\{ \{\text{A, Catherine}\}, \Big\{ \{\text{E, kiss}\}, \{\text{A, Henry}\} \Big\} \Big\} \Big\}$

Because of the selectional restrictions just assumed, it isn't possible to *merge* $\{\text{T, present}\}$ or $\{\text{T, past}\}$ with the set $\{\{\text{A, Catherine}\}, \{\{\text{E, kiss}\}, \{\text{A, Henry}\}\}\}$

---

[3] Actually, I will later suggest that the present tense operator immediately selects only referential arguments of type s. See section 4.1.

prior to *merge* with $\{\text{T, after}\}$. This prevents the overgeneration observed in (28).

At this point, a question remains concerning when and where the structure in (29) *merges* with a main clause structure. Here are two plausible alternatives: First, the semantic representation for the tense-featureless structure corresponding to *Catherine leave* might optionally select an argument of type t prior to merge with one of the tenses. Otherwise, the semantic representation for the tense-featured structure *Catherine left* might optionally select an argument of type t. Of course, both alternatives come at a cost. Under our current assumptions, allowing tense featureless structures to optionally select a type t argument would license structures like (30), which might be spelled out as **Catherine left Catherine kissed Henry.*

$$\text{(30)}\qquad *\left\{\begin{array}{l}\{\text{T, past}\},\\ \qquad\left\{\begin{array}{l}\{\ \{\text{A, Catherine}\}, \{\text{E, leave}\}\ \},\\ \quad\left\{\begin{array}{l}\{\text{T, past}\},\\ \quad\{\ \{\text{A, Catherine}\}, \{\ \{\text{E, kiss}\}, \{\text{A, Henry}\}\ \}\ \}\end{array}\right\}\end{array}\right\}\end{array}\right\}$$

Similarly, allowing a tense-featured structure to optionally select a type t argument would license structures like (31).

$$\text{(31)}\qquad *\left\{\begin{array}{l}\{\ \{\text{T, past}\}, \{\ \{\text{A, Catherine}\}, \{\text{E, leave}\}\ \}\ \},\\ \qquad\quad\{\ \{\text{T, past}\}, \{\ \{\text{A, Catherine}\}, \{\ \{\text{E, kiss}\}, \{\text{A, Henry}\}\ \}\ \}\ \}\end{array}\right\}$$

To prevent these instances of overgeneration, I will assume semantically that the tenses introduce a special referential argument with a distinct type n. Revising their feature sets to reflect this assumption, we adopt $\{\text{N, present}\}$

and {N, past}. This prevents generation of the structures in (30) and (31), but it doesn't shed any light on the question of when and where temporal modifiers can merge with independent structures.

For the sake of concreteness I will assume the first alternative — event or state structures may optionally select a temporal argument. I will offer some justification for this choice in section 4.3. So, our syntax will generate structures of the following sort:

(32)
$$\left\{\begin{array}{l} \{\text{N, past}\}, \\ \quad \left\{\begin{array}{l} \{\ \{\text{A, Catherine}\}, \{\text{E, leave}\}\ \}, \\ \quad \left\{\begin{array}{l} \{\text{T, after}\}, \\ \quad \{\ \{\text{A, Catherine}\}, \{\ \{\text{E, kiss}\}, \{\text{A, Henry}\}\ \}\ \} \end{array}\right\} \end{array}\right\} \end{array}\right\}$$

We are now in a position to present our DRT-based semantic framework, which will map syntactic structures like that in (32) to *Discourse Representation Structures* suitable for model-theoretic interpretation. In chapter 3, I introduce the framework and define a DRS construction algorithm, and in chapter 4, I discuss the semantics of tense and temporal modification, justify the type-distinction between *events* and *states* and provide a compositional analysis of our core data.

Chapter 3

Discourse Representation Theory

The semantic framework provided by Discourse Representation Theory is particularly suitable for our purposes because of its use of semantically-typed *discourse referents* or *DRs* as constants of a formally-defined *DRS-language*, thus allowing for perspicuous reference to arbitrary individuals, events, states and times. DRT is also convenient insofar as many of my assumptions concerning tense and aspect have been previously formalized in a DRT setting (Kamp & Reyle 1993).

DRT provides an algorithm for translating (a subset of) well-formed syntactic structures into well-formed *Discourse Representation Structures* (or DRSs), formulae of the DRS-language. However, the "top-down" construction algorithm developed in Kamp & Reyle 1993 invites the criticism that it involves non-compositional translation rules (Groenendijk & Stokhof 1989). The methodological commitment to compositionality requires, roughly, that we compose the semantic representations of particular sentences from the semantic representation of the individual lexical items therein. Importantly, this commitment also requires semantic composition to work in harmony with the *syntactic structures* of our natural language data.[1]

3.1 Discourse Representation Structures

Before I present the DRS-construction algorithm, I will offer a brief informal description of our end goal: formulae of the DRS-language, Discourse Representation Structures. Let K be the semantic type of DRSs. A DRS consists of a pair $\langle \mathrm{U}, \mathrm{C} \rangle$, where U is a *universe* — a set of discourse referents (DRs) — and C is a *condition set* — a set of conditions on DRs. A DRS corresponding to (32) is provided in (33).

(33) $$\left\langle \{a_0, a_1, e_0, e_1, t_0, \mathsf{n}\}, \left\{ \begin{array}{l} a_0\text{: Catherine,} \quad a_1\text{: Henry,} \\ e_0\text{: } \mathtt{leave}(a_0), \quad e_1\text{: } \mathtt{kiss}(a_0, a_1), \\ t_0\text{: } \mathtt{include}(\mathtt{time}(e_0)), \\ t_0\text{: } \mathtt{after}(\mathtt{time}(e_1)), \\ \mathsf{n}\text{: } \mathtt{after}(\mathtt{time}(e_0)) \end{array} \right\} \right\rangle$$

The first element of the DRS in (33) is its *universe*; it includes the DRs a_0, a_1, e_0, e_1, t_0, and n. As mentioned above, DRs come in various semantic types (which will map onto distinct domains in our models). Here I distinguish between various DR types with lowercase Roman letters: let DRs of type a denote *individuals*, let DRs of type e denote *events*, let DRs of type t denote *times* (intervals), and let n be the utterance time. Later, we will let DRs of type s denote *states*.[2] The subscript indices distinguish among DRs within a

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[1] The inquisitive reader might consult Amblard et al. 2010, Kruijff-Korbayová 1998 and Bary & Haug 2011, *inter alia*, for illustrations of DRT in a variety of alternative grammatical frameworks.

[2] I assume here without argument that the eventualities involved in the interpretation of *Catherine left after she kissed Henry* are of type e. Criteria for the distinction between

given type and have no further significance.

The second element of the DRS in (33) is its *condition set*, which contains seven conditions, roughly: (i) the name of a_0 is *Catherine*, (ii) the name of a_1 is *Henry*, (iii) e_0 is the event of *Catherine leaving*, (iv) e_1 is the event of *Catherine kissing Henry*, (v) t_0 is a time including the event-time of e_0, (vi) t_0 follows the event-time of e_1, and (vii) the utterance time n follows the event-time of e_0. For each condition in (33), there is a primary argument followed by a colon. The expressions following the colons place conditions on their primary arguments. Proper names and predicates are distinct categories in the DRS-language, hence the typographical distinction between 'Catherine,' 'Henry' and '`leave`'. Note that *predicates* take one or more arguments in addition to a primary argument. Of course, these arguments are themselves DRs and are primary arguments of independent conditions in C.

A DRS corresponding to *Catherine loved Henry after he loved her* is given in (34). Note the type s eventualities and the distinct constraint on t_0, the reference time.

(34)
$$\left\langle \{a_0, a_1, s_0, s_1, t_0, \mathsf{n}\}, \left\{ \begin{array}{ll} a_0\text{: Catherine}, & a_1\text{: Henry}, \\ s_0\text{: }\mathtt{love}(a_0, a_1), & s_1\text{: }\mathtt{love}(a_1, a_0), \\ t_0\text{: }\mathtt{in}(\mathtt{time}(s_0)), & \\ t_0\text{: }\mathtt{after}(\mathtt{time}(s_1)), & \\ \mathsf{n}\text{: }\mathtt{after}(\mathtt{time}(s_0)) & \end{array} \right\} \right\rangle$$

---

events and *states* is discussed in section 4.1, and further eventuality types are discussed in section 5.2.

The distinct constraints on reference times will follow from special semantic representations introduced for temporal modification structures in section 4.2. For now, we will concentrate on defining the minimal representations and mechanisms required to construct DRSs for simple sentences without temporal modification.

3.2 Extensions to the lexicon $\mathcal{L}$

The derivation of a DRS requires (in addition to the to-be-specified construction algorithm) an extension of our lexicon $\mathcal{L}$. In addition to the attribute $\mathfrak{l}$ specifying feature sets, we define two methods, $\mathcal{V}$ and $\mathcal{I}$, and four more attributes $\mathfrak{a}$, $\mathfrak{e}$, $\mathfrak{s}$ and $\mathfrak{t}$.

The method $\mathcal{V}$ is a function that maps each lexical item in the language under investigation to a function of the form $\lambda i.\langle \rho_i, \kappa_{[\rho_i]}\rangle$, where ρ varies over basic semantic types, and i varies over the set of natural numbers: thus ρ_i indicates a *typed DR variable* with *index* i. The notation $\kappa_{[\rho_i]}$ is meant to indicate the presence of one or more tokens of ρ_i within the element κ. To make our discussion more concrete, consider (35), which defines $\mathcal{V}$ for four lexical items.

$$(35)\qquad \begin{bmatrix} & & \vdots \\ \{\text{A, Henry}\} & \mapsto & \lambda i\,.\,\langle a_i,\ \langle\{a_i\}\,,\ \{a_i : \text{Henry}\}\rangle\rangle \\ \{\text{A, Catherine}\} & \mapsto & \lambda i\,.\,\langle a_i,\ \langle\{a_i\}\,,\ \{a_i : \text{Catherine}\}\rangle\rangle \\ \{\text{E, leave}\} & \mapsto & \lambda i\,.\,\langle e_i,\quad \lambda a'.\langle\{e_i\}\,,\ \{e_i : \texttt{leave}(a')\}\rangle\rangle \\ \{\text{S, love}\} & \mapsto & \lambda i\,.\,\langle s_i,\quad \lambda a''.\,\lambda a'.\langle\{s_i\}\,,\ \{s_i : \texttt{love}(a', a'')\}\rangle\rangle \\ & & \vdots \end{bmatrix}$$

For now, it is sufficient to note that $\mathcal{V}$ yields functions whose forms fit the abstract characterization above. For the moment, we suppress a detailed characterization of the κ elements, which as we see in (35) may be internally complex to varying degrees.

The functions output by $\mathcal{V}$ are passed to the method $\mathcal{I}$, which draws on the (natural number) attributes $\mathfrak{a}$, $\mathfrak{e}$, $\mathfrak{s}$ and $\mathfrak{t}$ to supply indices to these functions, according to the following definition:

(36) For input of the form $\lambda i.\langle a_i, \kappa_{[a_i]}\rangle$:

$$\begin{aligned}\mathcal{I}(\lambda i.\langle a_i, \kappa_{[a_i]}\rangle) &= \lambda i.\langle a_i, \kappa_{[a_i]}\rangle(\mathfrak{a}) \\ &= \langle a_{\mathfrak{a}}, \kappa_{[a_{\mathfrak{a}}]}\rangle\end{aligned}$$

For input of the form $\lambda i.\langle e_i, \kappa_{[e_i]}\rangle$:

$$\begin{aligned}\mathcal{I}(\lambda i.\langle e_i, \kappa_{[e_i]}\rangle) &= \lambda i.\langle e_i, \kappa_{[e_i]}\rangle(\mathfrak{e}) \\ &= \langle e_{\mathfrak{e}}, \kappa_{[e_{\mathfrak{e}}]}\rangle\end{aligned}$$

For input of the form $\lambda i.\langle s_i, \kappa_{[s_i]}\rangle$:

$$\begin{aligned}\mathcal{I}(\lambda i.\langle s_i, \kappa_{[s_i]}\rangle) &= \lambda i.\langle s_i, \kappa_{[s_i]}\rangle(\mathfrak{s}) \\ &= \langle s_{\mathfrak{s}}, \kappa_{[s_{\mathfrak{s}}]}\rangle\end{aligned}$$

For input of the form $\lambda i.\langle t_i, \kappa_{[t_i]}\rangle$:

$$\begin{aligned}\mathcal{I}(\lambda i.\langle t_i, \kappa_{[t_i]}\rangle) &= \lambda i.\langle t_i, \kappa_{[t_i]}\rangle(\mathfrak{t}) \\ &= \langle t_{\mathfrak{t}}, \kappa_{[t_{\mathfrak{t}}]}\rangle\end{aligned}$$

Otherwise: $\mathcal{I}(\mathrm{X}) = \mathrm{X}$

By definition (36), $\mathcal{I}$ is sensitive to the semantic type of its argument's DR variable ρ_i. For example, when ρ_i is of type a, the attribute $\mathfrak{a}$ (a natural number) is passed to the argument of $\mathcal{I}$. In effect, $\mathcal{I}$ transforms its argument's *typed DR variable* into a *typed DR* with an index equal to the correspondingly-typed attribute of $\mathcal{L}$. (An explanation of just how the attribute values are appropriately set will be described in section 3.4 below.) The pairs produced by $\mathcal{I}$, we will call *preliminary semantic representations* or *PSR-pairs* for short.

This concludes the extension of the lexicon $\mathcal{L}$ as required for the compositional derivation of Discourse Representation Structures.

3.3 The semantic interpretation operations

Given our extended lexicon, we are ready to begin defining the operators that will play direct roles in the specification of our bottom-up DRS construction algorithm. First, we define the ι-operator for *insertion* of PSR-pairs into syntactic structures.

(37) For all feature sets X in the domain of $\mathcal{V}$:

$$\iota(\mathrm{X}) = \mathcal{I}(\mathcal{V}(\mathrm{X}))$$

The ι-operator maps any feature set X to a PSR-pair $\langle \rho,\ \kappa_{[\rho]} \rangle$, now letting ρ vary over properly indexed, typed DRs.

The structure in (39) illustrates the result of applying the ι-operator to both of the feature sets in (24), repeated as (38).

(38) $\big\{ \ \{\text{A, Catherine}\}, \{\text{E, leave}\} \ \big\}$

(39) $$\left\{ \begin{array}{l} \langle\ a_0,\ \langle\{a_0\},\ \{a_0 : \text{Catherine}\}\rangle\ \rangle, \\ \qquad\quad \langle\ e_0,\ \lambda a'.\langle\{e_0\},\ \{e_0 : \texttt{leave}(a')\}\rangle\ \rangle \end{array} \right\}$$

Similarly, we can derive the structure in (41) by applying the ι-operator to all three feature sets in (40).

(40) $$\Big\{\ \{\text{A, Catherine}\}, \Big\{\ \{\text{S, love}\}, \{\text{A, Henry}\}\ \Big\}\ \Big\}$$

(41) $$\left\{ \begin{array}{l} \langle a_0,\ \langle\{a_0\},\ \{a_0 : \text{Catherine}\}\rangle\rangle, \\ \qquad\quad \left\{ \begin{array}{r} \langle s_0,\ \lambda a''.\,\lambda a'.\langle\{s_0\},\ \{s_0 : \texttt{love}(a', a'')\}\rangle\rangle, \\ \langle a_1,\ \langle\{a_1\},\ \{a_1 : \text{Henry}\}\rangle\rangle \end{array} \right\} \end{array} \right\}$$

Precisely *how* each DR is *uniquely* indexed will be seen when the ι-operator is integrated into the final DRS construction algorithm itself. For now, suffice it to say that each application of the ι-operator results in an incrementation of the $\mathcal{L}$-attribute ($\mathfrak{a}$, $\mathfrak{e}$, $\mathfrak{s}$ or $\mathfrak{t}$) invoked by the method I.

Before we define the next operator required by our bottom-up DRS construction algorithm, the α-operator, we must characterize the expressions we find as the second elements of PSR-pairs. As above, let κ vary over these expressions, which we will call *preliminary Discourse Representation Structures* or *p-DRSs* for short. We will classify each expression κ by recursively defining an infinite class of p-DRS types using the basic types of the DRS-language (a, e, s, t, K) as building blocks.

(42) Let Π vary over p-DRS types:

a. K is a p-DRS type.

PSR (p-DRS)	Type
$\langle a_0,\ \langle\{a_0\},\ \{a_0 : \text{Catherine}\}\rangle\rangle$	K
$\langle a_1,\ \langle\{a_1\},\ \{a_1 : \text{Henry}\}\rangle\rangle$	K
$\langle e_0,\ \lambda a'.\langle\{e_0\},\ \{e_0 : \texttt{leave}(a')\}\rangle\rangle$	$\langle a, K\rangle$
$\langle s_0,\ \lambda a''.\,\lambda a'.\langle\{s_0\},\ \{s_0 : \texttt{love}(a', a'')\}\rangle\rangle$	$\langle a, \langle a, K\rangle\rangle$

Table 3.1 PSR pairs with emphasized p-DRS elements and p-DRS types

b. $\langle a, \Pi\rangle$, $\langle e, \Pi\rangle$, $\langle s, \Pi\rangle$ and $\langle t, \Pi\rangle$ are p-DRS types.

c. Nothing else is a p-DRS type.

Recall the PSR-pairs derived above, repeated in table 3.1 with their p-DRS elements emphasized. The p-DRSs introduced by the proper names *Henry* and *Catherine* are of the basic type K — they have the form $\langle \mathrm{U}, \mathrm{C}\rangle$. The p-DRS introduced by *leave*, however, is of a complex type — it is a function from (expressions of type) a to K. The p-DRS introduced by *love* is of an even more complex type — a function from a to a function from a to K.

Now that we have characterized expressions of the p-DRS language, we need to define a class of *merge* operations over p-DRSs (parallel to (but not to be confused with) the syntactic operation *merge* from section 2.2). If each p-DRS is of type K, the merge operation required is straightforward — indeed, it is essentially identical to the commutative operation over proper DRSs '$\oplus$' given in many dynamic formulations of DRT. For all κ, κ' of type K:

(43) $\kappa \oplus \kappa' = \Big\langle\ \mathrm{U}_\kappa \cup \mathrm{U}_{\kappa'},\ \mathrm{C}_\kappa \cup \mathrm{C}_{\kappa'}\ \Big\rangle$

On the other hand, what if one p-DRS is of type K while another is of some complex type? By definition (42), exactly one p-DRS expression of type K is embedded in every p-DRS κ. We adopt the following notation:

(44) For any p-DRS κ:

a. Let $\Downarrow(\kappa)$ denote the unique expression of type K in κ.

b. Let $\kappa_{[\Downarrow(\kappa)\mapsto\kappa']}$ denote κ with $\Downarrow(\kappa)$ mapped to κ'.

Given these notational conventions, and still letting Π vary over p-DRS types (including all complex p-DRS types), we can define a class of merge operations $\mathcal{M}$ with types of the form $\langle\Pi,\langle K,\Pi\rangle\rangle$. Let μ vary over elements of $\mathcal{M}$, and let context decide which μ is appropriate for a given application.

(45) $\mu(\kappa) = \lambda\kappa'_{\langle K\rangle}.\kappa_{[\Downarrow(\kappa)\mapsto\Downarrow(\kappa)\oplus\kappa']}$

We leave it as an open question whether it is desirable to define a more general class of merge operations. In any case, such operations will not be necessary for the small fragment under consideration here.

We are finally in a position define the α-operator.

(46) For all sets X and for all PSRs Y, Z such that $\mathrm{X} = \{\mathrm{Y}, \mathrm{Z}\}$:

If κ_{Y} is a function whose domain includes ρ_{Z}:

$$\alpha(\mathrm{X}) = \langle\rho_{\mathrm{Y}},\ \mu(\kappa_{\mathrm{Y}}(\rho_Z))(\kappa_{\mathrm{Z}})\rangle$$

Otherwise, $\alpha(\mathrm{X})$ is undefined.

With the α-operator thus defined, we can illustrate its application to the syntactic-semantic structure in (39) repeated as (47):

(47)
$$\left\{ \begin{array}{l} \big\langle\; a_0,\ \langle\{a_0\},\ \{a_0 : \text{Catherine}\}\rangle\; \big\rangle\,, \\ \qquad\quad \big\langle\; e_0,\ \lambda a'.\langle\{e_0\},\ \{e_0 : \texttt{leave}(a')\}\rangle\; \big\rangle \end{array} \right\}$$

The output of the α-operator applied to the structure in (47) is given in (48).

(48)
$$\big\langle\; e_0,\ \langle\{a_0, e_0\},\ \{a_0 : \text{Catherine}, e_0 : \texttt{leave}(a_0)\}\rangle\; \big\rangle$$

Next, let's consider application of the α-operator to the structure in (41), repeated as (49).

(49)
$$\left\{ \begin{array}{l} \langle a_0,\ \langle\{a_0\},\ \{a_0 : \text{Catherine}\}\rangle\rangle, \\ \qquad\quad \left\{ \begin{array}{r} \langle s_0,\ \lambda a''.\,\lambda a'.\langle\{s_0\},\ \{s_0 : \texttt{love}(a', a'')\}\rangle\rangle, \\ \langle a_1,\ \langle\{a_1\},\ \{a_1 : \text{Henry}\}\rangle\rangle \end{array} \right\} \end{array} \right\}$$

Because the structure in (49) was generated by two applications of the syntactic operation *merge*, two applications of the α-operator are required in the derivation of its PSR. First, we apply the α-operator to inner set in (49).

(50)
$$\left\{ \begin{array}{l} \langle a_0,\ \langle\{a_0\},\ \{a_0 : \text{Catherine}\}\rangle\rangle, \\ \qquad\quad \big\langle\; s_0,\ \lambda a'.\,\langle\{a_1, s_0\}, \{a_1 : \text{Henry}, s_0 : \texttt{love}(a', a_1)\}\rangle\; \big\rangle \end{array} \right\}$$

Another application of the α-operator yields the following PSR:

(51)
$$\big\langle\; s_0,\ \langle\{a_0, a_1, s_0\}, \{a_0 : \text{Catherine}, a_1 : \text{Henry}, s_0 : \texttt{love}(a_0, a_1)\}\rangle\; \big\rangle$$

The final operation required in our DRS construction algorithm, I call the ω-operator.

(52) For any PSR X $= \langle \rho, \kappa \rangle$ such that κ is of type K:

$$\omega(\mathrm{X}) = \kappa_{\mathrm{X}}$$

Intuitively, the purpose of the ω-operator is to end a derivation by liberating well formed DRSs from their residual referential arguments (which will play no role in the model-theoretic interpretation).

Application of the ω-operator to (48) and (51) yield (53) and (54), respectively:

(53) $\langle \{a_0, e_0\},\ \{a_0\!:\!\text{Catherine}, e_0\!:\!\texttt{leave}(a_0)\}\rangle$

(54) $\langle \{a_0, a_1, s_0\}, \{a_0 : \text{Catherine}, a_1 : \text{Henry}, s_0 : \texttt{love}(a_0, a_0)\}\rangle$

The truth conditions for DRSs are given in terms of *verifying embeddings* into models. I will not discuss this in detail; readers are referred to Kamp 1981, Kamp & Reyle 1993, Kamp et al. 2011.

3.4 The DRS construction algorithm

With these operations defined and illustrated, we are finally in a position to step back and consider the DRS construction algorithm itself:

(55) Given an arbitrary syntactic structure and a lexicon $\mathcal{L}$:

a. Traverse the tree.[3] For each node X, if X is in the domain of $\mathcal{V}$:

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[3] I suppress a detailed discussion of tree-traversal algorithms.

apply $\iota(\mathrm{X})$, and:

(i) If $\rho_{\iota(\mathrm{X})}$ is of type a add 1 to $\mathfrak{a}$ in $\mathcal{L}$.

(ii) If $\rho_{\iota(\mathrm{X})}$ is of type e add 1 to $\mathfrak{e}$ in $\mathcal{L}$.

(iii) If $\rho_{\iota(\mathrm{X})}$ is of type s add 1 to $\mathfrak{s}$ in $\mathcal{L}$.

(iv) If $\rho_{\iota(\mathrm{X})}$ is of type t add 1 to $\mathfrak{t}$ in $\mathcal{L}$.

b. Let $n = 0$. Traverse the tree. For each node X, if X = {Y, Z} and Y and Z are PSRs:

If κ_{Y} is a function whose domain includes ρ_{Z}:

apply $\alpha(\mathrm{X})$ and add 1 to n.

If $n > 0$, loop this step. Else proceed.

c. If the result of the preceding steps is a PSR X:

apply $\omega(\mathrm{X})$.

Otherwise, the output is undefined.

Assuming a syntactic tree with n terminal constituents hosting lexical items (whose PSRs are such that successive applications of the α-operator yields a PSR suitable for the ω-operator), a DRS may be derived by n applications of the ι-operator, $n-1$ applications of the α-operator and one application of the ω-operator.

Chapter 4

Tense, aspect and temporal modification

In this chapter, I consider data involving tense (section 4.1), temporal modification (section 4.2) and aspectual coercion (section 4.3). These data motivate the distinction between DRs of type e and s, and permit us to define a formal semantic analysis of *before* and *after* as converse relations that is consistent with the core data introduced in the introduction.

In order to proceed, we need to enrich our DRS-language. Let it include the predicates listed in table 4.1. Note that they conveniently correspond to relations in the class of models defined in section 1.1. Let these resources also be available in the p-DRS language.

DRS-language predicate	↦	model-theoretic relation
`before`		$\prec$
`after`		$\succ$
`in`		$\sqsubseteq$
`include`		$\sqsupseteq$
`time`		T

Table 4.1 Temporal predicates and corresponding relations.

4.1 Tense and aspect

In this section, I propose semantic representations for {N, present} and {N, past}, and I derive PSRs for unmodified expressions like *Catherine loves Henry* and *Catherine kissed Henry.*

In considering the distinction between present and past tenses, I will also revisit claims made in section 2.3, where I introduced the category features E and S (foreshadowing the semantic types e and s for DRs in the DRS-language) and suggested that the semantic representations corresponding to the tenses select arguments of either type, e or s. What motivates these claims?

Davidson (1967) argued that logical forms for action sentences must include "event" variables, if they are to capture, for example, the entailment relation in (56).

(56) Catherine kissed Henry before she left.

$\models$ Catherine kissed Henry.

Indeed, as Davidson acknowledged, the motivation for events as entities in the semantic representation language extends beyond action sentences: "the problems we have been mainly concerned with are not at all unique to talk of actions: they are common to talk of events of any kind." In particular, logical forms for sentences including the lexical items we have assigned to category S must also include "event variables" as they too participate in entailment relations, as in (57).

(57) Catherine loved Henry before he loved her.
$\models$ Catherine loved Henry.

Davidson's arguments motivate a distinct *type* for eventualities, but as of yet, we have no compelling reason for assuming, e.g., that *leave* and *love* introduce *two distinct types* of eventualities.

However, observe the distinction in the acceptability of (58a) and (58b):

(58) a. #Catherine leaves.
b. Catherine loves Henry.

In English, simple present tense cannot be used to report Catherine's departure at the utterance time: for this purpose, (58a) is ungrammatical (cf. *Catherine is leaving*).[1] On the other hand, (58b) is perfectly natural for reporting Catherine's love for Henry at the utterance time.

We require some mechanism to capture these facts in our grammar. Assigning distinct eventuality types to *leave* and *love* allows us to use selectional restrictions in order to prevent present tense interpretation of eventualities like Catherine's departure. Let's suppose that {N, present} selects for states. Let the method $\mathcal{V}$ in $\mathcal{L}$ include the following mapping:

(59) $\{\text{N, present}\} \mapsto \Big\langle\ \mathsf{n},\ \lambda s.\Big\langle\{\mathsf{n}\},\Big\{\ \mathsf{n}:\mathtt{in}(\mathtt{time}(s))\ \Big\}\Big\rangle\ \Big\rangle$

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[1] In section 4.3, we will briefly discuss acceptable uses of (58a), and my analysis will be compatible with the account of present tense given here.

The second element of the PSR pair in (59) is of type $\langle s, K\rangle$; it requires a type s argument. The PSR pair itself has n as its referential argument, an assumption I adopted in section 2.3 in order prevent the tenses from acting as temporal modifiers to independent structures. The p-DRS introduced by {N, present} in (59) places one condition on the deictic time n provided by context: n is a subinterval of the time corresponding to the type-s argument.

Let's proceed by considering the structure in (60), a set including a present tense PSR and the PSR derived in (51) in section 3.3.

(60)
$$\left\{ \begin{array}{l} \Big\langle \ \mathsf{n},\ \lambda s.\big\langle\{\mathsf{n}\},\{\ \mathsf{n}:\mathtt{in}(\mathtt{time}(s))\ \}\big\rangle\ \Big\rangle, \\ \qquad \left\langle\ s_0,\ \left\langle\{a_0, a_1, s_0\},\ \left\{\begin{array}{l} a_0:\text{Catherine}, \\ a_1:\text{Henry}, \\ s_0:\mathtt{love}(a_0, a_1) \end{array}\right\}\right\rangle\ \right\rangle \end{array} \right\}$$

Application of the α-operator to the set in (60) yields the PSR in (61).

(61)
$$\left\langle\ \mathsf{n},\ \left\langle\{a_0, a_1, s_0, \mathsf{n}\},\ \left\{\begin{array}{l} a_0:\text{Catherine}, \\ a_1:\text{Henry}, \\ s_0:\mathtt{love}(a_0, a_1)\,, \\ \ \mathsf{n}:\mathtt{in}(\mathtt{time}(s_0)) \end{array}\right\}\right\rangle\ \right\rangle$$

The condition on n allows (but does not require) the left bound of s_0 to precede n, in line with intuitions concerning the truth-conditions of (58b).

We now turn to the semantics of {N, past}. Unlike {N, present}, it seems that the past tense selects either eventuality type, e or s.

(62) a. Catherine left.

b. Catherine loved Henry.

Let's begin by adopting a semantic representation of the past tense that captures our intuitions concerning the interpretation of (62a); that is, the past tense should require n to follow the time of Catherine's departure.

(63) $\{\text{N, past}\} \mapsto \left\langle\ \mathsf{n},\ \lambda\epsilon. \left\langle \{\mathsf{n}\}, \left\{\ \mathsf{n} : \mathtt{after}(\mathtt{time}(\epsilon))\ \right\}\right\rangle\ \right\rangle$

Consider the application of the past tense PSR to the structure in (48), which yields the structure in (64).

(64) $$\left\langle\ \mathsf{n}, \left\langle \{a_0, e_0, \mathsf{n}\}, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ e_0 : \mathtt{leave}(a_0), \\ \mathsf{n} : \mathtt{after}(\mathtt{time}(e_0)) \end{array} \right\} \right\rangle\ \right\rangle$$

Does definition (63) yield the correct interpretation for *Catherine loved Henry*? Applied to the PSR derived in (51), the past tense yields the PSR in (65).

(65) $$\left\langle\ \mathsf{n}, \left\langle \{a_0, a_1, s_0, \mathsf{n}\}, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ s_0 : \mathtt{love}(a_0, a_1), \\ \mathsf{n} : \mathtt{after}(\mathtt{time}(s_0)) \end{array} \right\} \right\rangle\ \right\rangle$$

This representation requires the state of Catherine loving Henry to precede the utterance time n. Without context, this does seem to follow from *Catherine loved Henry*. However, the inference is cancelable, suggesting that it should not be entailed by the semantics.

(66) Catherine loved Henry, and indeed, she still does.

We might preserve our semantic analysis of past tense, however, if we build into our models a *subinterval property*, requiring that a state anchored at an interval t must correspond to a set of substates, itself mapped one-to-one with the set of all subintervals of t. We might then claim that the state corresponding to the maximal interval is the default interpretation, but that a substate might be preferred for pragmatic reasons — say, if the present state of affairs is not at issue or not relevant to the discourse, or if the speaker has (or is known to have) insufficient evidence to make claims about the present state of affairs. This issue requires further investigation; it will come up again when we consider the semantics of *before* and *after* in the following section.

4.2 Temporal modification and aspect

We are now in a position to investigate the semantics of *before* and *after*. I suggested in section 2.3 that these lexical items ought to introduce p-DRSs that select for eventualities and that they themselves contribute a distinct referential argument of type t. In this section, I will motivate these claims, and I will propose a semantic analysis of *before* and *after* and demonstrate its consistency with the core data discussed in the introduction.

First, let's explore the claim that *before* and *after* select for eventualities. This claim might be doubted on the grounds of (67), given the supposition that *midnight* denotes a time.

(67) Catherine left after midnight.

If we conclude that *before* and *after* select times, we will be forced to claim that expressions like *Catherine kissed Henry* can sometimes be of type t, perhaps through the intervention of some covert lexical item like {T, time} (cf. Stowell 1996). On the other hand, we might maintain that *before* and *after* select for eventualities if we concede that expressions like *midnight* themselves denote some type of eventuality. This is the analysis I will adopt at present, though further investigation is clearly required.

Let's now consider the analysis of *before* and *after* given in the following extension to the method $\mathcal{V}$ from our lexicon $\mathcal{L}$:

$$(68) \quad \begin{bmatrix} & & \vdots \\ \{\text{T, before}\} & \mapsto & \lambda i.\Big\langle\ t_i,\ \lambda\epsilon.\Big\langle\{t_i\},\Big\{\ t_i : \texttt{before}(\texttt{time}(\epsilon))\ \Big\}\Big\rangle\ \Big\rangle \\ \{\text{T, after}\} & \mapsto & \lambda i.\Big\langle\ t_i,\ \lambda\epsilon.\Big\langle\{t_i\},\Big\{\ t_i : \texttt{after}(\texttt{time}(\epsilon))\ \Big\}\Big\rangle\ \Big\rangle \\ & & \vdots \end{bmatrix}$$

Note that on this analysis, *before* and *after* select for an eventuality and locate this eventuality's time prior to or following a type t referential argument.

First, let's apply this analysis in the derivation of the temporal modifier *after Catherine kissed Henry.* The structure in (69) includes a PSR corresponding to the lexical item *after* as well as the PSR corresponding to the expression *Catherine kissed Henry.*

$$(69) \quad \left\{ \begin{array}{l} \Big\langle\ t_0,\ \lambda\epsilon.\Big\langle\{t_0\},\Big\{\ t_0 : \texttt{after}(\texttt{time}(\epsilon))\ \Big\}\Big\rangle\ \Big\rangle, \\ \qquad \left\langle\ e_0,\ \left\langle\{a_0, e_0\}, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ e_0 : \texttt{kiss}(a_0, a_1) \end{array} \right\}\right\rangle\ \right\rangle \end{array} \right\}$$

Application of the α-operator to (69) yields the PSR in (70).

(70)
$$\left\langle t_0, \left\langle \{a_0, e_0, t_0\}, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ e_0 : \texttt{kiss}(a_0, a_1), \\ t_0 : \texttt{after}(\texttt{time}(e_0)) \end{array} \right\} \right\rangle \right\rangle$$

In our analysis, because *before* and *after* select either eventuality type, there is no significant difference in the derivation of, e.g., the expression *before Henry loved Catherine.*

(71)
$$\left\langle t_0, \left\langle \{a_0, a_1, s_0, t_0\}, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ s_0 : \texttt{love}(a_1, a_0), \\ t_0 : \texttt{before}(\texttt{time}(s_0)) \end{array} \right\} \right\rangle \right\rangle$$

How do the structures in (70) and (71) merge with independent structures? I assume, as I did in section 2.3, that temporal modifiers merge with eventuality structures, not with tensed structures. (I will justify this assumption in section 4.3.) So, we want eventuality structures to optionally select times. The question is, what condition should an eventuality place on its temporal argument? Consider again the core data involving type e eventualities.

(72) a. Catherine kissed Henry before Catherine left.
b. Catherine left after Catherine kissed Henry.

Intuitively, the time of Catherine's departure should follow the time of the kiss. This would follow if the time introduced by the temporal modifier were equal to the event time. But the data doesn't justify such a strong claim. The weaker relation of inclusion is sufficient. Accordingly, we will assume the weak hypothesis unless further data requires something stronger.

Consequently, our claim that events optionally select for a temporal modifier can be formalized by adding lexical items, e.g., {E, leave, time}, to $\mathcal{L}$ and by extending the method $\mathcal{V}$ in $\mathcal{L}$ to include, e.g.:

(73) $\{\text{E, leave, time}\} \mapsto$

$$\lambda i\,.\left\langle e_i,\ \lambda a'.\,\lambda t'.\left\langle \{e_i\}\,, \left\{ \begin{array}{l} e_i : \texttt{leave}(a'), \\ t' : \texttt{includes}(\texttt{time}(e_i)) \end{array} \right\} \right\rangle \right\rangle$$

Let's explore the analysis developed so far by combining a t-selecting structure of type e with a temporal modifier. The following example illustrates:

(74)
$$\left\{ \begin{array}{c} \left\langle\ e_0,\ \lambda t'.\left\langle \{a_0, a_1, e_0\}\,, \left\{ \begin{array}{l} a_0 : \text{Catherine} \\ e_0 : \texttt{leave}(a_0), \\ t' : \texttt{includes}(\texttt{time}(e_0)) \end{array} \right\} \right\rangle \right\rangle, \\ \left\langle\ t_0,\ \left\langle \{a_0, a_1, e_1, t_0\}, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ e_1 : \texttt{kiss}(a_0, a_1), \\ t_0 : \texttt{after}(\texttt{time}(e_1)) \end{array} \right\} \right\rangle \right\rangle \end{array} \right\}$$

When the α-operator is applied to the structure above, the following output is derived:

(75)
$$\left\langle\ e_0,\ \left\langle \{a_0, a_1, e_0, e_1, t_0\}\,, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ e_0 : \texttt{leave}(a_0), \\ e_1 : \texttt{kiss}(a_0, a_1), \\ t_0 : \texttt{includes}(\texttt{time}(e_0))\,, \\ t_0 : \texttt{after}(\texttt{time}(e_1)) \end{array} \right\} \right\rangle \right\rangle$$

Subsequent composition with the {N, past} PSR yields the following structure, the Preliminary Semantic Representation of the expression *Catherine left after she kissed Henry.*

(76) $$\left\langle \mathsf{n}, \left\langle \{a_0, a_1, e_0, e_1, t_0, \mathsf{n}\}, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ e_0 : \texttt{leave}(a_0), \\ e_1 : \texttt{kiss}(a_0, a_1), \\ t_0 : \texttt{includes}(\texttt{time}(e_0)), \\ t_0 : \texttt{after}(\texttt{time}(e_1)), \\ \mathsf{n} : \texttt{after}(\texttt{time}(e_0)) \end{array} \right\} \right\rangle \right\rangle$$

The PSR for the expression *Catherine kissed Henry before she left* is derived in essentially the same manner, the main difference being the relation introduced by *before*.

(77) $$\left\langle \mathsf{n}, \left\langle \{a_0, a_1, e_0, e_1, t_0, \mathsf{n}\}, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ e_0 : \texttt{kiss}(a_0, a_1), \\ e_1 : \texttt{leave}(a_0), \\ t_0 : \texttt{includes}(\texttt{time}(e_0)), \\ t_0 : \texttt{before}(\texttt{time}(e_1)), \\ \mathsf{n} : \texttt{after}(\texttt{time}(e_0)) \end{array} \right\} \right\rangle \right\rangle$$

Note that both (76) and (77) satisfy the model in figure 1.1 from the introduction. Further note that neither model satisfies figure 1.4.

Now let's continue to explore our analysis of temporal modification by combining a t-selecting structure of type s with a temporal modifier, while keeping in mind the attested interpretations discussed for our core data involving type-s eventualities.

(78) a. Catherine loved Henry before Henry loved Catherine.

b. Henry loved Catherine after Catherine loved Henry.

Because it might be the case that the interval of Catherine's love for Henry overlaps or includes his love for her, we need to suppose a different relation between states and reference times. The following example illustrates a possible extension of the method $\mathcal{V}$ for an additional lexical item $\{\text{S, love, time}\}$:

(79) $$\{\text{S, love, time}\} \mapsto \lambda i\,.\left\langle s_i,\ \lambda a''.\,\lambda a'.\,\lambda t'.\left\langle \{s_i\}\,,\left\{\begin{array}{l} s_i : \texttt{love}(a', a'') \\ t' : \texttt{in}(\texttt{time}(s_i)) \end{array}\right\}\right\rangle\right\rangle$$

The following example illustrates a t-selecting s-structure which has been merged with a t-structure from (71).

(80) $$\left\{\begin{array}{c} \left\langle s_0,\ \lambda t'.\left\langle \{a_0, a_1, s_0\}\,,\left\{\begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ s_0 : \texttt{love}(a_0, a_1), \\ t' : \texttt{in}(\texttt{time}(s_0)) \end{array}\right\}\right\rangle\right\rangle, \\ \left\langle t_0,\ \left\langle \{a_0, a_1, s_1, t_0\},\left\{\begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ s_1 : \texttt{love}(a_1, a_0), \\ t_0 : \texttt{before}(\texttt{time}(s_1)) \end{array}\right\}\right\rangle\right\rangle \end{array}\right\}$$

Application of the α-operator to the structure above yields the PSR below:

(81) $$\left\langle s_0,\ \left\langle \{a_0, a_1, s_0, s_1, t_0\}\,,\left\{\begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ s_0 : \texttt{love}(a_0, a_1), \\ s_1 : \texttt{love}(a_1, a_0), \\ t_0 : \texttt{in}(\texttt{time}(s_0))\,, \\ t_0 : \texttt{before}(\texttt{time}(s_1)) \end{array}\right\}\right\rangle\right\rangle$$

Subsequent composition with a PSR of $\{\text{N, past}\}$ yields the final PSR for the expression *Catherine loved Henry before he loved her*:

(82)
$$\left\langle \mathsf{n},\ \left\langle \{a_0, a_1, s_0, s_1, t_0, \mathsf{n}\}\, , \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ s_0 : \texttt{love}(a_0, a_1), \\ s_1 : \texttt{love}(a_1, a_0), \\ t_0 : \texttt{in}(\texttt{time}(s_0))\, , \\ t_0 : \texttt{before}(\texttt{time}(s_1))\, , \\ \mathsf{n} : \texttt{after}(\texttt{time}(s_0)) \end{array} \right\} \right\rangle \right\rangle$$

Here is the PSR for the expression *Henry loved Catherine after she loved him*:

(83)
$$\left\langle \mathsf{n},\ \left\langle \{a_0, a_1, s_0, s_1, t_0, \mathsf{n}\}\, , \left\{ \begin{array}{l} a_0 : \text{Henry}, \\ a_1 : \text{Catherine}, \\ s_0 : \texttt{love}(a_0, a_1), \\ s_1 : \texttt{love}(a_1, a_0), \\ t_0 : \texttt{in}(\texttt{time}(s_0))\, , \\ t_0 : \texttt{after}(\texttt{time}(s_1))\, , \\ \mathsf{n} : \texttt{after}(\texttt{time}(s_0)) \end{array} \right\} \right\rangle \right\rangle$$

Recall figure 1.2, which falsifies *Catherine loved Henry before he loved her* and satisfies *Henry loved Catherine after she loved him.* The PSR in (83) requires that some time t_0 within the state s_0 of Henry loving Catherine follows the time corresponding to the state of Catherine loving Henry, just as it should. In the case of the PSR in (82), some time t_0 within the state of Catherine loving Henry must fall before the time corresponding to the state of Henry loving Catherine. Since no such time can be located in the model in figure 1.2, (82) comes out false.[2]

Next, recall figure 1.3. It falsifies (82), on the same reasoning as given in the previous paragraph. The PSR in (83), however, does not provide the

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[2] I am implicitly assuming here that we are working with maximal states, not with mere substates or subintervals of Henry's or Catherine's love. Cf. section 4.1.

representation we need for the interpretation on which *Henry loved Catherine after she loved him* turns out to be true in figure 1.3. In the next section, I will extend the lexicon with operators that allow for limited *aspectual coercion*, thus deriving appropriate representations for the weak interpretation of *after*-sentences.

4.3 Aspectual coercion

In the previous two sections, relying on the distinction between events and states, types e and s, I defined a mapping from the tenses, *present* and *past*, the temporal modifiers, *before* and *after*, and t-selecting variants of *leave* and *love* to PSRs, and I derived logical forms compatible with most of the attested interpretations of our core data presented in chapter 1. However, a number of important questions remain. What motivates the assumption that *leave* and *love* select for type t arguments? Shouldn't the tenses also introduce (or select for) type t arguments? And how can the account developed above be made to accommodate the weak interpretation discussed in connection with (7b) and illustrated by the model in figure 1.3?

In this section, I present data that has motivated accounts of *aspectual coercion*, a shift from one eventuality type to another (Moens & Steedman 1988). I illustrate three varieties of aspectual coercion. Each variety considered will allow us to revisit issues raised above. First, I motivate the assumption that temporal modifiers are hosted by eventualities by considering coercion from events to *habitual states*. Second, I consider an analysis of English *perfect* constructions as coercion from events to *result states*, in contrast to Reichenbach's (1947) account, where tenses introduce reference times. Finally, I argue for a coercion operation mapping states to inceptive events, and I use it to derive a weak readings for (7b).

4.3.1 Coercion from events to habitual states

Let's begin the discussion of coercion from events to habitual states by recalling the present tense data from (58) in section 4.1, where I claimed that expressions like *Catherine leaves* and *Catherine kisses Henry* are unavailable for describing presently occurring events. However, note that these expressions are acceptable if they are interpreted as descriptions of habitually recurring events (Moens & Steedman 1988, Smith 1997). For example, (84) is perfectly natural.

(84) Catherine kisses Henry often.

The temporal adverbial *often* forces a habitual interpretation, but is not absolutely necessary if the context favors a habitual interpretation.

(85) a. What does Catherine do before she leaves?
b. She kisses Henry.

The question raised in (85a) provides sufficient discourse context to provoke a habitual interpretation for (85b).

Similarly, the introduction of temporal modifiers headed by *before* and *after* makes habitual interpretations salient for present tense events, as (86a) illustrates. Perhaps surprisingly, temporal modifiers headed by *before* and *after* are odd with present tense states, as in (86b).

(86) a. Catherine leaves after she kisses Henry.
b. ?Catherine loves Henry before he loves her.

Let's first consider (86a). Let's assume a predicate `habit` that maps events to *habitual states*.[3] For expressions like (84), we might claim that *often* introduces the predicate `habit`, but we also need to allow covert coercion for simple sentences with contextually triggered habitual interpretations. Covert coercion might be implemented in a variety of ways . For concreteness, I adopt a covert lexical item {S, habit}.

(87) $\{\text{S, habit}\} \mapsto \lambda i. \Big\langle\ s_i, \lambda e. \langle \{s_i\}, \{s_i : \texttt{habit}(e)\}\rangle\ \Big\rangle$

Roughly, then, we can account for (86a) with the following structure:

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[3] This assumes that our model-theoretic eventuality structure is more highly articulated than I suggested in section 1.1: we need our models to specify that certain states consist of recurring events.

(88)

$$\left\{\begin{array}{l} \{\text{N, present}\}, \\ \quad \left\{\begin{array}{l} \{\text{S, habit}\}, \\ \quad \left\{\begin{array}{l} \big\{ \{\text{A, Catherine}\}, \{\text{E, leave}\} \big\}, \\ \quad \left\{\begin{array}{l} \{\text{T, after}\}, \\ \quad \left\{\begin{array}{l} \{\text{A, Catherine}\}, \\ \quad \big\{ \{\text{E, kiss}\}, \{\text{A, Henry}\} \big\} \end{array}\right\} \end{array}\right\} \end{array}\right\} \end{array}\right\} \end{array}\right\}$$

Now we can see why I have assumed that eventuality type expressions take temporal modifiers prior to composition with tense: the present tense state described by (86a) should be defined in terms of the recurrence of the sequence of events — Catherine leaving after kissing Henry. The interpretation that would result if tensed structures selected for temporal modifiers would require Catherine's habit of leaving to precede an instance of her kissing Henry. In sum, temporal modification must precede aspectual coercion, and aspectual coercion must precede composition with tense. Consequently, I assume that temporal modification precedes composition with tense generally speaking.

4.3.2 Coercion from events to result states

Now let's turn to our second example of aspectual coercion. The English perfect construction, Moens & Steedman (1988) argue, triggers a coercion from an event to its result state. Consider example (89).

(89) a. After midnight, Catherine kissed Henry.

b. After midnight, Catherine had kissed Henry.

Whereas (89a) locates the event of the kiss strictly after midnight, (89b) admits an interpretation which locates the event of the kiss at (or possibly before) midnight. According to Moens & Steedman's theory, (89b) indicates that the *result state* of the kiss follows the time given by the temporal adjunct *after midnight*.

Let $\mathcal{V}$ in $\mathcal{L}$ provide the following mapping for a feature structure $\{\text{S, have}\}$.

(90) $$\{\text{S, have}\} \mapsto \lambda i. \left\langle\ s_i,\ \lambda e. \left\langle\ \{s_i\},\ \{s_i\ :\ \texttt{result}(e)\}\ \right\rangle \right\rangle$$

The syntactic structure underlying the PSR below was derived by merging the temporal modifier with the structure headed by e_0, and then by merging the resulting structure with $\{\text{S, have}\}$. The resulting PSR yields the interpretation equivalent to that derived from a simple past tense main clause, as in (89a).

(91) $$\left\langle\ s_0, \left\langle\ \{a_0, a_1, e_0, e_1, s_0, t_0\}, \left\{ \begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ e_0 : \texttt{kiss}(a_0, a_1)\,, \\ e_1 : \text{midnight}, \\ s_0 : \texttt{result}(e_0)\,, \\ t_0 : \texttt{after}(e_1)\,, \\ t_0 : \texttt{includes}(\texttt{time}(e_0)) \end{array} \right\} \right\rangle \right\rangle$$

On the other hand, the syntactic structure underlying the PSR in (92) was derived by merge of the e_0 structure with the PSR of $\{\text{S, have, time}\}$ given by (93), followed by a merge with the temporal modifier. This yields the interpretation where the result state is situated after midnight, leaving it open where the event of the kiss itself falls in relation to midnight.

(92) $$\left\langle\ s_0, \left\langle\ \{a_0, a_1, e_0, e_1, s_0, t_0\}, \left\{\begin{array}{l} a_0 : \text{Catherine}, \\ a_1 : \text{Henry}, \\ e_0 : \texttt{kiss}(a_0, a_1)\,, \\ e_1 : \text{midnight}, \\ s_0 : \texttt{result}(e_0)\,, \\ t_0 : \texttt{after}(e_1)\,, \\ t_0 : \texttt{in}(\texttt{time}(s_0)) \end{array}\right\} \right\rangle \right\rangle$$

(93) $$\{\text{S, have, time}\} \mapsto$$
$$\lambda i. \left\langle\ s_i, \lambda e. \lambda t. \langle \{s_i\}, \{s_i\ :\ \texttt{result}(e)\,, t\ :\ \texttt{in}(\texttt{time}(s_i))\}\rangle\ \right\rangle$$

Note that we don't have to suppose that result states strictly follow their inceptive events, e.g., they could share initial instants; the relevant conditions in (92) require a subinterval of the result state of Catherine's kiss to follow midnight.

Here, as in sections 4.1 and 4.2, I introduce reference times only when an overt temporal modifier is present. This is in contrast to the classic analysis of the tenses from Reichenbach 1947 where *tense* always introduces a reference time to mediate between eventuality time and utterance time (cf. Hornstein 1990, Stowell 1996, Kamp & Reyle 1993). Reichenbach motivates this analysis of tense on the basis of perfect constructions. Since Moens & Steedman's (1988) coercion-based account of the perfect does not *rely* on reference time, it can be completely divorced from the semantics of tense, at least for our purposes.

So far, I've presented two varieties of *e*-to-*s* coercion. Given that we have these two options, why isn't event to result state coercion available for the interpretation of present tense in the expression *Catherine leaves*, analagous to the event to habitual state coercion discussed above? This question I leave for future work.

4.3.3 Coercion from states to inceptive events

We are now ready to consider the last variety of coercion listed at the outset of this section: coercion from states to inceptive events. Recall the claim from section 1.3 that (7b), repeated as (94), might be judged true in models like that illustrated in figure 1.3, where Henry's love endures past the inception of Catherine's love, but not for long, as his love fades long before Catherine's.

(94) Henry loved Catherine after she loved him.

I propose to derive this interpretation with the help of a feature structure $\{\text{E, incep}\}$ with a semantic representation akin to those of $\{\text{S, habit}\}$ and $\{\text{S, result}\}$ in basic form, but selecting for a type s argument (and optionally selecting for a type-t argument), contributing a type-e argument, and introducing a predicate `incep`.

(95) $\{\text{E, incep}\} \mapsto \lambda i.\ \big\langle e_i,\ \lambda s.\ \big\langle \{e_i\}, \big\{\ e_i : \texttt{incep}(s)\ \big\}\big\rangle\big\rangle$

Just as coercion from event to result state is triggered by *have*, coercion from state to inceptive event is triggered by *begin* or *start*.

(96) Catherine began to love Henry.

And like coercion from event to habitual state (but unlike coercion from event to result state) coercion from state to inceptive event is possible without an overt lexical trigger, given appropriate context.

Returning to (94), let's suppose that {E, incep} is merged with the embedded stative structure *she loved him.* This is illustrated by the structure in (97), with the PSRs for each constituent derived by our semantic interpretation operations.

(97)
$$\left\{ \begin{array}{l} \langle e_0,\ \lambda s.\ \langle \{e_0\}, \{\ e_0 : \texttt{incep}(s)\ \} \rangle \rangle\ , \\ \qquad \left\langle s_0,\ \left\langle\ \{a_0, a_1, s_1\}, \left\{ \begin{array}{l} a_0 : \text{Henry}, \\ a_1 : \text{Catherine}, \\ s_1 : \texttt{love}(a_1, a_0) \end{array} \right\} \right\rangle \right\rangle \end{array} \right\}$$

Application of the α-operator to the structure in (97) yields the PSR in (98).

(98)
$$\left\langle e_0,\ \left\langle\ \{a_0, a_1, s_1, e_0\}, \left\{ \begin{array}{l} a_0 : \text{Henry}, \\ a_1 : \text{Catherine}, \\ s_1 : \texttt{love}(a_1, a_0), \\ e_0 : \texttt{incep}(s_1) \end{array} \right\} \right\rangle \right\rangle$$

From this point, the derivation is straightforward. The PSR in (98) combines with that of {T, after}, and the result is input to an independent *t*-selecting PSR. It is the result of this operation that combines with the PSR of {N, past}, yielding the structure in (99).

(99) $$\left\langle \mathsf{n}, \left\langle \{a_0, a_1, s_0, s_1, e_0, t_0, \mathsf{n}\}, \left\{ \begin{array}{l} a_0 : \text{Henry}, \\ a_1 : \text{Catherine}, \\ s_0 : \mathtt{love}(a_0, a_1)\,, \\ s_1 : \mathtt{love}(a_1, a_0)\,, \\ e_0 : \mathtt{incep}(s_1)\,, \\ t_0 : \mathtt{after}(\mathtt{time}(e_0))\,, \\ t_0 : \mathtt{in}(\mathtt{time}(s_0))\,, \\ \mathsf{n} : \mathtt{after}(\mathtt{time}(s_0)) \end{array} \right\} \right\rangle \right\rangle$$

Applying the ω-operator to the PSR in (99), we are left with a DRS that is satisfied by the model in figure 1.3, i.e., there is an embedding such t_0 follows the inception e_0 of s_1, Catherine's love for Henry, while falling within the interval of s_0, Henry's love for Catherine.

Before we leave this topic, let's pause to recall the relation of our analysis with that of Beaver & Condoravdi 2003a,b. I have explored their suggestion of treating coercion as a pragmatic option, but I have adopted `incep` instead of their *earliest*. Assuming that our class of models is appropriately restricted to ensure that inceptive events provide initial bounds for their result states, the two proposals make identical claims in the temporal domain. The motivation for my choice comes from the aspectual domain. Though the influential theory of Moens & Steedman 1988 does not make this coercion operation explicit, they do acknowledge the existence of data that support the inceptive operator proposed here:

(100) When Pete came in, I knew that something was wrong.

(Moens & Steedman 1988: 24)

Further, the assumption mentioned above, concerning the temporal relation between inceptive events and results states, is already satisfied if we take `incep` to be the converse of `result`. The latter operator, as we have seen, *is* explicitly proposed in Moens & Steedman's theory.

The three varieties of aspectual coercion we have considered do not exhaust the range of coercion operators that have been proposed. Rather, we have limited our discussion to those examples of aspectual coercion that bear on our immediate questions concerning tense, temporal modification and the event/state distinction. In the next chapter, we will see that there is much work do be done in the theory of aspectual coercion. The simple theory developed to account for our core data in this chapter provides a promising basis for this research.

Chapter 5

Summary and future work

I began this report by considering an intuitively promising converse analysis of *before* and *after* and an interpretation puzzle that posed a problem for this analysis. In chapters 2 through 4, I presented a formal grammar for a fragment of English. Syntactically, this grammar is broadly compatible with current minimalist research, but the semantic representations it assigns to lexical items are suitable as inputs to a compositional DRS-construction algorithm. Thus our logical forms are formulae of the DRS-language, suitable for model-theoretic interpretation. I adopted simple analyses of the tenses and the temporal modifiers, and I argued for a simple theory of aspect and aspectual coercion. Crucially, these analyses and arguments allow us to preserve the intuitive analysis of *before* and *after* and to account for the interpretations of our core data. Unlike the converse analysis presented by Beaver & Condoravdi (2003b), the analysis presented here predicts mutual entailment for the pair in (1) without stipulating instantaneous events, and it makes both weak and strong readings of *after* sentences available without recourse to interval-to-instant coercion. And as we have seen, it also sheds light on the syntax of temporal modification and simplifies the analysis of tense by avoiding the introduction of covert reference times.

However, the analyses I offer have yet to be applied to the full range of complex data in English (not to mention the range of complex data from other languages) involving the interaction of tense, aspect and temporal modification. In fact, there are even unresolved issues concerning *before* and *after* constructions — additional data that should be covered by a comprehensive theory. I will use this final chapter to discuss promising avenues for future work, first in the theory of *before* and *after* (section 5.1) and then more broadly in the theory of tense, aspect and temporal modification (section 5.2).

5.1 Theory of *before* and *after*

First, let's consider open issues in the theory of *before* and *after*. I will highlight three areas for further research: Negative Polarity Items in *before*- and *after*-modifiers, non-veridical interpretations of *before*-modifiers, and the truth-conditions of simultaneous events in *after*-structures.

First let's consider questions concerning the licensing behaviors of *before* and *after* with respect to Negative Polarity Items (or NPIs, cf. Higginbotham 1988, Landman 1991, Sánchez-Valencia et al. 1993, Beaver & Condoravdi 2003b). The data in (101) suggest that *before* licenses the NPI *ever* and that *after* does not.

(101) a. Catherine loved Henry before he ever loved her.
b. #Catherine loved Henry after he ever loved her.

According to Ladusaw (1979), NPIs are licensed in *downward monotone envi-*

ronments. Beaver & Condoravdi (2003b) argue that both the quantificational analysis and their converse analysis predict the licensing behavior of *before* and *after*. My converse analysis, on the other hand, predicts that both *before* and the strong (default) interpretation of *after* should license NPIs, while the weak interpretation of *after* should not.

Indeed, there is reason to think that the licensing conditions for NPIs under *after* is more complex than (101) suggests. First, note that *long after* does license *ever* (Condoravdi 2010):

(102) Catherine loved Henry long after Henry ever loved her.

I cannot address the semantics of *long* and *ever* in detail here. I presume that *long* forces a strong reading and thereby licenses *ever*. But can *after* ever license an NPI without the help of *long*? In answer, I offer the data in (103), were (103b) in particular provides a plausible instance of *after* licensing an NPI without support from *long*:

(103) a. Catherine left before there was any hope of seeing Henry.
b. ?Catherine left after there was any hope of catching the train.

While I cannot attempt to do justice to the full range of questions concerning NPIs in *before*- and *after*-modifiers here, I take it that the data in (102) and (103b) constitute problems for both the quantificational analysis and the implementation of the converse analysis presented by Beaver & Condoravdi. The alternative analyses of *before* and *after* compared in this report all require careful examination in light of NPI facts.

Next, let's consider issues concerning the *veridicality* or *non-veridicality* of the eventualities introduced by *before*-modifiers. Again, these are issues not only for my proposal, but also for alternative analyses, so I will begin by considering how these alternatives fare with respect to relevant data. Recall the quantificational analysis in (8). The universal quantification over times introduced by *before* predicts the trivial truth of a token of the form *A before B* whenever there are no times at which the clause *B* is true; i.e., it always allows for *nonveridical* interpretations of *before*-clauses. And indeed, nonveridical interpretations of *before*-adjuncts do arise, as in (104) from Beaver & Condoravdi (2003b: 41).

(104) Mozart died before he finished the Requiem.

Landman (1991) accepts this prediction of the quantificational analysis, claiming that *veridical* interpretations of *before*-clauses are the result of pragmatic inference. However, as Beaver & Condoravdi argue, nonveridical interpretations are possible only in very particular contexts. Tentatively, (104) invites a nonveridical interpretation of the *before*-clause because the main clause asserts Mozart's death, rendering a veridical interpretation of the temporal clause highly implausible. In (105), on the other hand, a nonveridical interpretation of the *before*-clause is quite difficult to achieve, despite the independent implausibility of a veridical *before*-clause interpretation.

(105) Aristotle taught Alexander before he was a Scientologist.

Resolving the antecedent of *he* to *Aristotle*, it follows from (105) that Aristotle was a Scientologist: any model that satisfies (105) also satisfies the proposition *Aristotle was a Scientologist* (and similarly, *mutatis mutandis*, when *he* is resolved to *Alexander*). The quantificational analysis thus appears to overpredict the availability of nonveridical interpretations.

In contrast to the predictions of the quantificational analysis with respect to examples like (105), Beaver & Condoravdi's analysis in (10) makes *before*-clauses veridical by default (on the assumption that temporal operators like *earliest* are undefined for null intervals). In order to account for *nonveridical* uses of *before*-clauses as in (104), Beaver & Condoravdi (2003b) present an intensional revision of their analysis, in which *earliest*, if undefined in the world of evaluation, is interpreted relative to a closely related set of worlds — each world with a history identical to the world of evaluation except with respect to the circumstances described by the main clause. While the details are not our primary concern here, the important point is that Beaver & Condoravdi's analysis predicts veridical interpretations of *before*-clauses by default and provides an additional mechanism to derive their nonveridical counterparts, in contrast to the quantificational analysis, which predicts non-veridical interpretations of *before*-clauses by default and provides an additional mechanism to derive their veridical counterparts.

The semantic analysis developed in this report does not attempt to account for non-veridical interpretations of *before*-modifiers, but there is no reason in principle why we couldn't adopt an intensional revision of our DRS-language and follow Beaver & Condoravdi's account of nonveridicality.

Finally, let's consider an issue concerning the truth-conditions of *before*- and *after*-constructions relating simultaneous eventualities, again comparing our analysis to the alternatives previously discussed. On the quantificational analysis (106a) is necessarily false and (106b) is necessarily true, given that the main and subordinate clauses refer to the same eventuality.

(106) a. ?Catherine loved Henry before Catherine loved Henry.
b. ?Catherine loved Henry after Catherine loved Henry.

One might accept these predictions and argue that (106a) and (106b) are pragmatically infelicitous precisely because the former is a contradiction and the latter is a tautology. But consider a model wherein Henry and Catherine love each other simultaneously, satisfying (107b) and falsifying (107a).

(107) a. Catherine loved Henry before Henry loved Catherine.
b. Henry loved Catherine after Catherine loved Henry.

In this case, we have neither a contradiction in (107a) nor a tautology in (107b). But in what contexts would a speaker assent to (107b) with full knowledge of Henry and Catherine's simultaneous love? The question merits serious consideration, given the predictions of (8).

The converse analysis also inherits the difficulties discussed in connection with (106) and (107) because:

(108) For simultaneous, non-singleton intervals A and B:

  a. it will never be the case that there is an instant of time in A strictly *preceding* the earliest instant of time in B, and
  b. it will always be the case that there is an instant of time in A strictly *following* the earliest instant of time in B.

As in the case of the quantificational analysis, these predictions deserve further, careful consideration.

On my main analysis, (i.e., without the intervention of aspectual coercion), both items in (106) and (107) are predicted to be false. However, the introduction of the inceptive operator complicates things, and we have to consider in detail what model-theoretic constraints hold of the relation between states, their inceptive events and the intervals assigned to them by T. Suppose that the intervals of inceptive events provide left bounds for *open* intervals corresponding to result states. In this case, on inceptive readings, (106b) and (107b) will both be true, as they are in the quantificational analysis and in Beaver & Condoravdi's converse analysis. However, suppose that the intervals of inceptive events provide left bounds for *closed* intervals corresponding to result states. In this case, even on inceptive readings, (106b) and (107b) are predicted to be false. Which of these possibilities is to be preferred is a interesting question that deserves further research.

I have presented a number of open issues and questions involving the syntax, semantics and pragmatics of *before* and *after* constructions. Doubtless, there are a variety of other questions to be addressed — not the least of which are typological questions concerning possible counterparts to *before*- and *after*-constructions across a variety of languages. However, it is time to leave the theory of *before* and *after* and to turn to the broader issues raised concerning the theory of tense, aspect and temporal modification.

5.2 Theory of tense, aspect and temporal modification

In this report, I've discussed present and past tense, events and states, perfect constructions and the temporal relations *before* and *after*, and I've said next to nothing concerning "future" tense, progressive constructions and the possible existence of additional eventuality types, as evidenced by interesting data involving temporal expressions including *when, while, as, since, until, on, at, in, for, ...*

Before taking up some of these themes, we should note that, even restricting ourselves to present and past tense, what we have said so far cannot be the full story. We see this in *sequence of tense* phenomena. (My discussion is based on Stowell 2007.) Consider the expression *say*, which requires a *propositional* complement. In (109a), the embedded expression *loved* bears past tense morphology, and there are two possible interpretations: Catherine approximately said either "Henry loves me" (the *simultaneous* interpretation) or "Henry loved me" (the *past-shifted* interpretation). In (109b), *loves* bears present tense morphology and is appropriate only if Henry's love for Catherine includes not only the event time of Catherine's statement but also the utterance time of the expression (the *double-access* interpretation).

(109) a. Catherine said that Henry loved her.
b. Catherine said that Henry loves her.

The expression in (110a) exhibits the same possible interpretations as (109a), but in (110b), we see that present tense is prohibited in the propositional complement of *think*.

(110) a. Catherine thought that Henry loved her.
b. *Catherine thought that Henry loves her.

Here, I can only offer brief comments on these data. First, the lack of tense agreement and the attested interpretation of (109b) suggest that *loves* is licensed by the present tense, and by parity, that the tokens of *loved* in (109a) and (110a) are also licensed by their own tense item. The fact that the subordinate clause tenses interact with main clause tense in interpretation suggests that our semantic analysis of tense requires revision in order to facilitate this interaction. Finally, the contrast between the acceptability of (109b) and (110b) indicates there are differences in the contributions of *say* and *think* that need to examined in explaining these data. While, these data in particular are suggestive that the difference might involve eventuality type (since *say* is an event and *think* (in its use here) is a state), this hypothesis requires further empirical investigation, not to mention clarification of the mechanisms by which events and states might interact differently with embedded tenses.

Let's now explore some further issues that a comprehensive theory of tense and aspect should address. First, consider the data in (111).

(111) a. Catherine will leave tomorrow.
      b. Catherine leaves tomorrow.

The expression *will* in (111a), ostensibly inflected for present tense, receives a future interpretation. But so does the expression in (111b), where *will* is absent. In this case, a future interpretation is triggered by the temporal modifier, *tomorrow*, but future interpretation of present tense "events" is perhaps possible without a temporal modifier, if the context favors a future interpretation. So, we need an analysis of *will*, but we also need a mechanism for deriving future interpretations in its absence. I suspect that our theory of aspectual coercion might be key in deriving such future interpretations (note the oddity of *Catherine loves Henry tomorrow*); this issue requires further investigation.

Next, a comprehensive theory of tense and aspect should address *progressive* constructions, illustrated in (112).

(112) a. Catherine is leaving.
      b. Catherine is leaving after kissing Henry.
      c. Catherine is leaving after she kisses Henry.
      d. Catherine was leaving after she kissed Henry.

Again, the theory of aspectual coercion provides resources for the analysis of this data. For example, in Kamp & Reyle 1993, the progressive auxiliary maps events to *progressive states*. However, there are a number of issues to consider. While (112a) might describe an event in progress, (112b) and (112c) favor near future interpretations. And similarly (112d) might be used even if Catherine didn't actually leave as long as she intended or was preparing to leave.

These complications bring us to bigger question concerning our inventory of eventuality types. Moens & Steedman (1988) argue for a more highly articulated aspectual system, with the following subtypes for events: *points*, *culminations*, *processes* and *culminated processes*. They further argue that eventualities form complex *nuclei* that provide some of the basis for the coercions discussed so far (where our "events" are their "culminations") and many more besides (cf. figure 5.1). According to Moens & Steedman, nuclei consist of a preparatory process, a culmination and a result state. On their analysis, the progressive auxiliary selects processes as arguments, so interpretation of the examples in (112) requires coercion of *leave* (a culmination) to an associated preparatory process, which is then further coerced to a progressive state.

The eventuality types adopted by Moens & Steedman descend from the classification dating at least back to Vendler (1957) (who uses different terminology and does not recognize *points* as a distinct category). Indeed, this more fine grained approach to aspectual classification is commonplace in subsequent literature (e.g., Dowty 1979, Bach 1981, Smith 1997). It is supported by a wide

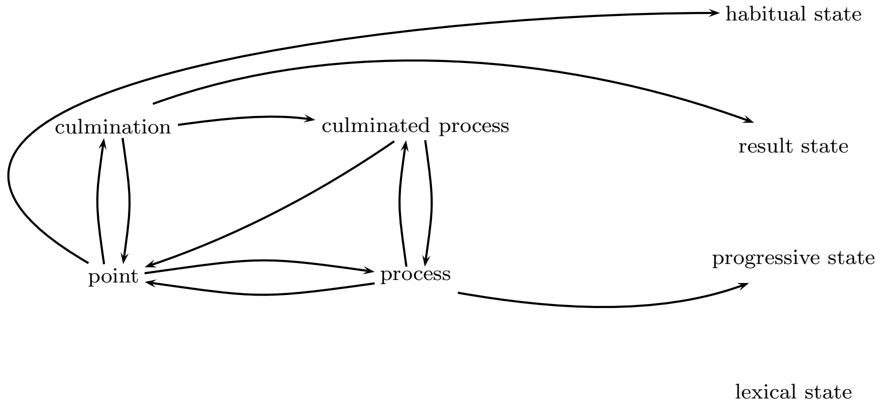

Figure 5.1 Moens and Steedman's aspectual transition network

range of diagnostics that involve not only interactions between tense, aspectual auxiliaries (*have* and *be* in perfect and progressive constructions, respectively) and embedded eventualities, but also interactions with a wide variety of temporal modifiers, including structures headed by *at*, *on*, *for* and *in.* Extension of the grammar provided here to account for these aspectual distinctions and the contribution of the various temporal and aspectual modifiers that have motivated these distinctions will be a huge task, but it is one that is essential to the enterprise of modeling the temporal dimensions of natural language semantics.

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