Aspectual Composition Using Weak Type Coercion

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May 1994

Report No. CMU-LCL-94-3

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April 11,1994

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Abstract:

Work on aspect has long focussed on classifications of linguistic expressions into aspectual types, or Vendler-classes. Typical Vendler-classes include states, processes, and events. Such classifications miss the important generalization about aspectual interpretation that it is a compositional process. It has been noted in the literature that terms can switch Vendler-classes; this has been called the category-switch problem. In our analysis, it is proposed that meanings and not expressions fall into aspectual classes, and that the aspectual type of a meaning is derived by a process of aspectual composition. This process operates on underlying *generalized activities* that are similar to the nuclei proposed by Moens & Steedman, which in turn resemble plans. The interplay between semantic selection for a certain aspectual type and the application of type-changing operators to the meanings of verb phrases and sentences that occurs during aspectual composition constitutes weak aspectual type coercion. Our *approach* is illustrated with a unification-based grammar fragment that accounts for aspectual composition with certain adverbials, such as *in a day* or *for an hour.*

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1. Introduction

Inventories of aspectual types date back to Aristotelian Metaphysics. Aristotle described a division into events, processes, and states. Similar divisions are employed in modern accounts of linguistic semantics; most notably, [Vendler, 1967]. Acknowledging his contributions to this area of linguistics, the term "Vendler-class" will be used in discussing aspectual types throughout this paper.

Vendler offered linguistic diagnostics for membership in Vendler-classes. Considering that Vendler wrote of "... time schemata presupposed by various verbs" ([Vendler, 1967], p. 98), it seems that he intended to assign linguistic expressions to Vendler-classes.

This is not the only way in which Vendler-classes can be brought to bear on the study of aspect and meaning. A second possibility is to regard membership in a Vendler-class or *aspectual type* as a property of the meanings of verb phrases (VPs) or sentences (Ss). In the framework of event semantics, the appropriate objects to which this property would apply are called "situations" or "eventualities". For consistency, the latter term (due to Bach) will be used throughout the discussion.

1.1. Summary of this Paper

The main points of this paper are as follows. First, we wish to argue that aspectual type is a property of meanings, and not of linguistic expressions.

Second, we wish to demonstrate that aspect is a compositional phenomenon. To this end, we will illustrate how pervasive the category-switch problem is, and how the Vendler-class of the meaning of a sentence depends not only on the verb, but also on arguments (e.g. the direct object of a transitive verb) and modifiers (e.g. certain adverbials).

Third, we wish to show that a process of aspectual composition involving weak aspectual type coercion over underlying generalized activities solves the category-switch problem.

Finally, a grammar fragment in a unification-based formalism will be presented that illustrates aspectual composition for adverbials like *in an hour* or *for a week.*

1.2. Structure of this Paper

Our analysis is based on event semantics, and we begin by summarizing a number of independent motivations for adopting this semantic framework. Vendler-classes have been discussed by various authors; some important proposals are reviewed in section 3. We then discuss problems with the traditional assignment of verbs and other linguistic expressions to Vendler-classes. Aspectual composition and some important properties of our approach to aspectual interpretation are described next After a brief overview of Head-driven Phrase Structure Grammar The analysis is illustrated with a unification-based grammar fragment for some adverbials.

1.3. A **Note on Terminology**

A confusing variety of terms is used in the study of aspect. Below is a brief summary. Vendler-classes are often characterized in terms of features or properties. Below are some of the terms that are used in the literature.

- **Extended in time,** Durative, nonpunctual, unbounded.
- **Not extended in time.** Nondurative, punctual, bounded.
- **With conclusion.** Conclusive, climax, telic, terminative.
- **Without conclusion.** Nonconclusive, no climax, atelic.

Aspectual classes themselves arc also named in a number of different ways.

- Event (Moens & Steedman), accomplishment (Vendler), kinesis (Taylor), performance (Kenny), developments (Mourelatos).
- Process (Moens & Steedman), activity (Vendler, Mourelatos), energeia (Taylor).
- Culmination (Moens & Steedman), achievement (Vendler), punctual occurrences (Mourelatos).

Wherever possible, the terminology of Moens & Steedman is adopted below.

2. Event Semantics

The earliest, widely influential formal theory of natural language semantics is the work of Richard Montague [Dowty et al., 1981, Thomason, 1974]). Montague's woik falls into the class of "Propositions, Properties, and Individuals" (PPI) theories of semantics.

In contrast, event semantics refers to a family of semantic theories that admit events as first-class objects into the theory of logical form. Advocates of this approach include [Davidson, 1967, Barwise, 1981]. The remainder of this section provides some motivation for event semantics, which will be adopted for this analysis of aspectual composition.

In this paper, we will confine ourselves to the "logical form" of sentences. A theory of logical form addresses certain aspects of meaning, but abstracts away from certain others. For example, a representation of the logical form of sentences includes an account of their literal meanings (e.g. addressing the truth conditions of the sentences), but ignores non-literal aspects of language. Non-literal meaning includes connotations of linguistic expressions, metaphoric meaning, and implicatures carried by sentences.

2.1. Introduction to Event Semantics

The main tenet of event semantics can be summarized as follows:

(1) Natural language sentences should be assigned logical forms that make reference to, quantify over, or form properties of, eventualities.

For example, consider the following sentence:

(2) Sandy eats a chocolate bar.

In a traditional, PPI theory, the semantic representation for this sentence would be as shown below:

(3) *eat'(sandy', chocolate-bar')*

The logical form in event semantics, on the other hand, might be as follows:

(4) *(3e)(eating(e)* A *actor(e, sandy')* A *patient(e, chocolate-bar'))*

Events can be used in different ways to represent the meaning of natural language sentences: The semantic object corresponding to a sentence could be of a number of different types. For example, the semantic representation of a sentence could be an existential quantification over an event, or it could be a property of events.

2.2. Motivations for Event Semantics

There are a number of motivations for admitting events into logical form. Rather than exhaustively argue this case here — which would leave little room for a discussion of aspectual composition — I simply summarize the supporting points, and provide pointers to the literature.

- **Naked infinitives perception sentences.** As aigued by [Barwise, 1981], so-called naked infinitives perception sentences require a degree of extensionality in their semantic representation that can best be achieved using eventualities. Consider the following contrasting pair.

  (5) a. Kim saw that Sandy erased the disk.
  b. Kim saw Sandy erase the disk.

  The first sentence could be assigned a higher-order PPI logical form, since it implies that Kim knows that Sandy erased the disk. The second sentence is more problematic for a PPI theory, however. The sentence is only making a statement about Kim's perception of an event, and not about Kim's understanding of it.

  Imagine that Kim was watching Sandy type commands into the computer. If Sandy had accidentally typed the command to erase the disk, then Kim saw Sandy erasing the disk, but (if past experience is a guide) neither Kim nor Sandy saw *that* Sandy erased the disk. In other words, an "epistemically neutral" way to represent an event is needed. PPI theories do not allow us to express epistemically neutral propositions, while event semantics provides us with a convenient semantic type for expressions of the form *Sandy erase the disk.*[1]

- **Intersective adverbials.** As argued by [Davidson, 1967], adverbials and the entailments between sentences with subsets of intersective adverbials can best be handled with an event variable at logical form. Consider, for example, the following sentences:

  (6) a. Jones buttered the toast in the bathroom, with a knife, at midnight.
  b. Jones buttered the toast in the bathroom.
  c. Jones buttered the toast at midnight.
  d. Jones buttered the toast.

[1] **Note, howevei; that an event-based theory faces problems with respect to sentences like "Kim saw that Sandy erased the disk."**

First, it should be noted that the first sentence entails the following three. But these is more than just these entailments; the sentences are describing the same event, which can best be captured with explicit event variables.

- **Quantification** over events **and nominalization.** As shown by [Parsons, 1989], p. 217, eventualities in logical form can be used to account for quantification over events:

  (7) a. In every burning, oxygen is consumed.
  b. Martha burned some wood.
  c. Oxygen was consumed.

  Event semantics allows us to formally represent the intuition that the burning event in the first sentence is the same type of event as the burning referred to in the second sentence. There is no type as suitable as an event for *a burning* in a PPI theory.

- Tense. Eventualities can be arranged in a temporal order, which (arguably) is a more elegant and more satisfying treatment of tense than e.g. Montague's time indices. For example, consider the following sentences:

  (8) a. Chris pulled over the car.
  b. He left the car,
  c. and entered the store.

  These sentences describe an intuitive sequence of events that can be captured by imposing an ordering on events.

- **Anaphoric reference to events.** Intuitively, expressions like *this* and *it* can be used to refer to eventualities — again, this is hard to represent without the ability to refer to events in a logical form. Consider the following examples:

  (9) a. Kim played loud music on his stereo,
  b. This upset his roommate.

- **Collective events.** Sentences can be used to refer to events that are clearly composed of smaller subevents. Consider the following examples:

  (10) a. Sandy changed every lightbulb.
  b. Chris jumped up and ran across the street.

  This can be captured most elegantly if events can be constructed out of smaller events in a compositional fashion. There are interesting parallels between this and the nominal domain; see [Thomason and Stalnaker, 1973, Partee, 1984, Bach, 1986].

3. A Brief History of Vendler-Classes

Vendler-classes have been used to classify linguistic expressions according to certain linguistic diagnostics. These diagnostics include co-occurrence with tense and aspectual moiphemes, and certain adverbials (see, e.g., [Dowty, 1979]). This section contains a brief survey of the main developments in this area.

3.1. Vendler's Original Work

Our starting point will be [Vendler, 1967]. A thorough review of this work can be found in [Verkuyl, 1989]. Vendler's classification includes four types; states, activities, achievements, and accomplishments. This is summarized in table 1.

	+ Continuous Tense	- Continuous Tense	
+ climax	**accomplishment**	**achievement**	instant of time
-climax	**activity**	**state**	time period

Table 1: Vendler's original classes

As shown in the table, Vendler's classes arc generated by three binary features:

- **Climax.** Does the event referred to by the verb have a climax or culmination?
- **Continuous tense.** Does the verb pass a number of "Continuous Tense Criteria" (CTC), such as occurring in progressive form, or occurring as an argument to the verbs *start* and *stop!*[2]
- **Temporal extension.** Is the activity referred to by the verb instantaneous, or does it occupy an interval of time?

Note that if the features were independent of each other (or "free") eight classes should be generated. In Vendler's classification, however, the "climax" feature only applies to items that meet the CTC, and the "temporal extension" feature only applies to items that do not meet the CTC. Below are canonical examples of each type of Vendler-class:

(11) a. Activity: He is running.
b. **Accomplishment:** He drew a circle.
c. **Achievement:** He crossed the finishing line.
d. State: He loves her.

An activity like *run* does not have a culmination, but it meets most CTC. The accomplishment of *draw a circle* culminates when the circle is finished, and also meets most CTC. *Cross the finishing line,* and example of an achievement, is considered to fail the CTC, and occurs in an instant of time. Finally, a state like *love somebody* fails the CTC, and occurs over an extended period of time.

3.2. Mourelatos

[Mourelatos, 1981] merges the separate hierarchies proposed by Vendler and Kenny into one set of aspectual types. UnderMourelatos'scheme,themaindivisionisbetweenstates,processes,andevents. The distinction between developments and punctual occurrences is treated as secondary. This is summarized in figure 1.

[2] **As noted by [Veriaiyl, 1989], many of Vendler's CTC are actually tests for agentivity, a feature not identified by Vendler.**

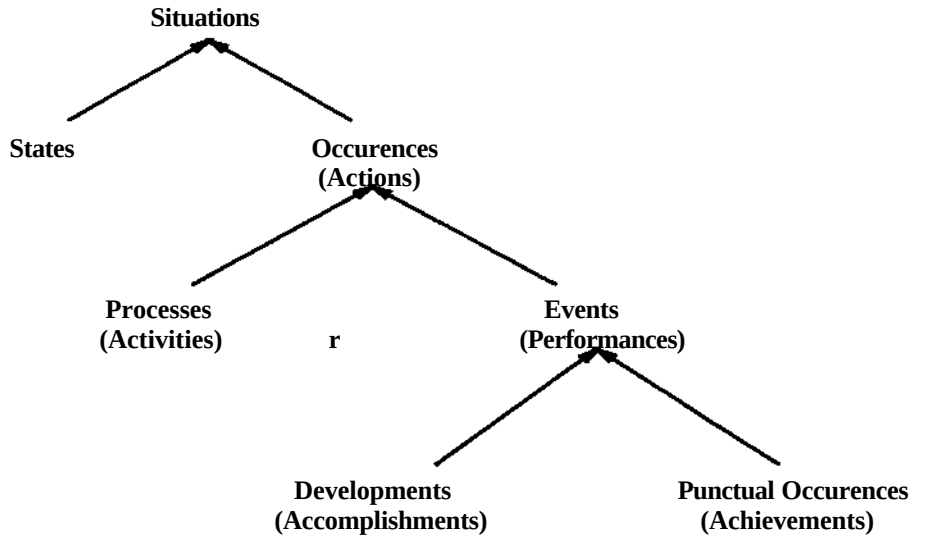


Figure 1: Mourelatos' aspectual types

3.3. Dowty

Probably the most comprehensive woik on linguistic diagnostics for Vendler-classes is [Dowty, 1979]. Again, Dowty sees his woik as an "aspectual classification of veibs". Below is a summary of Dowty's diagnostics. Note that the grammaticality judgments indicated below are taken from Dowty; they are not always compatible with the predictions made by our analysis.

- Co-occurrence **with** PP[/br]-Adverbials. Processes can take PP[/br]-adverbials. Events (or culminated process, in the terminology of Moens & Steedman) can't take PP[/br]-adverbials.

  (12) a. Chris ran for half an hour. *Chris ran a mile for half an hour.

- Co-occurrence **with** PP[//i]-Adverbials. Events (culminated processes) can take PP[i̇n]-adveibials. Processes, on the other hand, can't take PP[i̇n]-adverbials.

  (13) a. Kim climbed to the top in half an hour.
  b. He ran a mile in half an hour.
  c. *He ran in half an hour.

- **Complement to** *took an hour to—* Processes can't be a complement to *took an hour*, but events can.

- Progressive Form. Accomplishments and activities can occur in progressive form, while states and achievements can't take progressive form.

- Imperatives. States can't occur in the imperative form.

- **Complement to Stop and Start.** Activities and accomplishments can be complements to verbs like stop and start. States and achievements can't be complements to these verbs.

  (14) a. *She stopped/started loving him.
  b. *She stopped/started recognizing him.

  (15) a. She stopped/started running.
  b. She stopped/started drawing a circle.

3.4. Moens & Steedman

[Moens and Steedman, 1988] employ a finer-grained analysis of Vendler-classes than the standard division into states, processes, and events. There is a top-level distinction between events and states, and the discussion focuses on events. Events are divided into four types according to whether they are atomic or extended in time, and whether salient consequences are associated with them. This is summarized in table 2.

	atomic (time instant)	extended (time interval)
with salient consequences	**culmination**	**culminated process**
without salient consequences	**point**	**process**

Table 2: Moens & Steedman's event types

Below are canonical examples of each type:

- **Culmination:** He won the race.
- **Point:** He winked at them.
- **Culminated Process:** He built a house.
- **Process:** He is running.
- **State:** He understands regular expressions.

4. Problems with Vendler-Classes

Vendler's original account of aspectual classes can be summarized as follows:

1. Verbs fall into one of the Vendler-classes.
2. Membership in a Vendler-class can be ascertained using the diagnostics listed above.
3. If a verb can fall into more than one class, the verb is lexically ambiguous. This would be the case with the verb *run*, for example:

   (16) a. **Process:** Kim runs. (run_1)
   b. **Event:** Sandy ran a mile in twenty-five minutes. (run_2)

This account is not complete. As [Parsons, 1989] writes, "the diagnostics form clusters at best, but rarely coincide." This could be due to imperfect diagnostics, but there is a second, larger problem. When the nature of the exceptions to classification schemes and diagnostics is considered, it becomes clear that it is insufficient to specify the Vendler-class of a verb or more complex linguistic expression. If we stop there, an important generalization concerning the compositional and dynamic nature of aspectual composition is lost.

Expressions switch Vendler-class as they combine with other expressions. This observation shows that relying on a static classification of linguistic expressions is not sufficient. After presenting data in support of this argument in this section, an analysis of aspect that employs a compositional process of *aspectual composition* will be described.

4.1. Problems with Tense/Aspect Diagnostics

In this section, we list a number examples that violate the linguistic diagnostics for Vendler-class membership.

- **Progressive aspect on state verb.**

(17) a. **I** am living in the USA.
b. Sandy is standing by the Monongahela river.
c. You are looking well.
d. The picture is hanging over there.

- **Progressive aspect on achievement verb.**

(18) a. Chris is winning this game.
b. He is dying.
c. Kim was reaching the top.
d. Students were beginning to find it more difficult to meet the due dates.

- *Stoplstart* **taking states or achievements as complements.**

(19) a. Stop being a fool,
b. Stop being naughty.

4.2. Problems with Adverbial Diagnostics

- *In an hour* **taking achievement (point) as complement**

(20) Sandy reached the top in half an hour.

- *For an hour* **taking process as complement.**

(21) a. For hours Chris ate sandwiches.
b. For some time, Sandy was browsing through the book.
c. Kim has already walked for an hour.

43. Examples of Category-Switch

Category-switch occurs when an expression switches to a different Vendler-class. This is usually caused by the coercive action of other expressions that select for semantic values of a certain type. Consider the following example.

(22) a. Kim played the sonata.
b. Kim played the sonata for a few minutes.

In the absence of other material, the first sentence refers to a culminated event. This will be referred to as the "base" reading. The second sentence, however, is not referring to the entire sonata-playing event, but only to a few minutes worth of music-making. The event has become a process without a culmination. Below are some more examples, each with an indication of how the change is accomplished.

- **Culminated Process —• Process.** The culmination is stripped off.

(23) a. Kim crossed 5th Ave, but didn't see the bus coming. Kim never made it to the other side of the street,
b. When Chris built a house, he did most of the work himself.

- **Culmination or Point —> Process.** The atomic event is iterated.

(24) a. Niki Lauda won the Monaco Grand Prix for several years,
b. Kim hiccuped for half an hour.

- **Culminated Process —• Culminated Process.** One of the steps in the activity is picked.

(25) When Sandy built a house, his architect friend drew up the plans for free.

- **Culminated Process —• Culmination.** The extended eventuality is compressed to become punctual. This often co-occurs with an application of the iteration operator (which selects for an atomic event) or temporal event reference.

(26) a. When Chris built his house, he finally had enough space for his moth collection,
b. Sandy ran a mile every other day for four weeks, then increased the distance.

- **Culmination —• Culminated Process.** The steps in the activity (i.e. the preparatory process) are added to the culmination of the activity.

(27) Kim reached the top of Mount Fuji in two hours.

- **Process —> Culminated Process.** The culmination of the activity is added to the steps in the activity. The result is the entire activity.

In addition to modifiers or temporal reference (as in most examples above), the object(s) of the verb also play a role in aspectual composition. That is, the aspectual type of a sentence sometimes depends on the nature of the obligatory complements of the verb. Consider the following example:

(28) a. Kim built a house,
b. Kim built houses.

The first sentence is clearly an event By replacing the singular object with a plural, a "habitual" or iterated reading is obtained. This effect is even more striking if an ambiguous NP is used:

(29) a. Sandy shot arrows, (a number of arrows, one after the other)
b. Sandy shot arrows, (all at once)

Since *arrows* is ambiguous with respect to a distributed/group reading, two possible aspectual interpretations are obtained.

4.4. Response to the Category-Switch Problem

In the face of these observations, there are at least two options.

1. We can maintain that linguistic expressions can be assigned a Vendler-class statically, and postulate that many verbs are multiply ambiguous with respect to aspectual type.

2. We can assume that membership in a Vendler-class is a property of eventualities, and that the meanings of sentences obtain this property by a process of aspectual composition. This process would take into account the selectional properties of adverbials, tense morphemes, objects and other complements, etc.

The first option begs the question of how membership in a Vendler-class is determined as a compositional process that depends on the constituents in the sentence. Moreover, it does not express the generalization that all verbs seem to have a primary or "base" aspectual type, but may undeigo aspectual type coercion. For these reason, the second option will be explored below.

5. Aspectual Composition

In section 4.3 on the problem of category-switch, a number of processes were mentioned that occurred during category switch. Two of these processes are straightforward:

- Iterate an atomic event A to obtain a complex event B that consists of some number of A events repeated sequentially.

- Compress an extended event, which would take place over an interval of time, into an atomic event.

A number of other processes, however, made reference to an "activity", "steps in an activity", and "climax of an activity":

- Strip the culmination from a culminated process.
- Pick one of the steps in the activity.
- Add the steps in the activity to the culmination of the activity.
- Given the steps of an activity, form the entire activity.

We assume an underlying complex activity on which these operations can be performed. Moens & Steedman proposed the concept of a "nucleus" for this purpose; however, information bundles with the necessary structure have long been used in work on planning and language understanding. These connections will be further discussed in the remainder of this section.

5.1. Moens & Steedman's Nuclei

Moens and Steedman call the underlying structured activity a "nucleus". A nucleus consists of a preparatory process (extended over time), a culmination (punctual), and a consequent state. This is illustrated in figure 2.

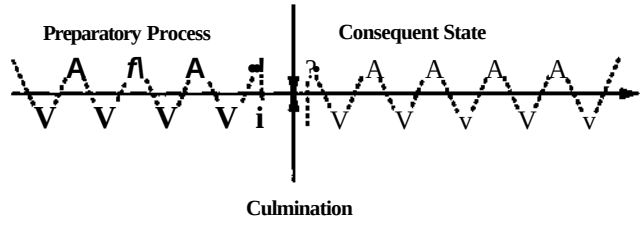


Figure 2: Moens & Steedman's nuclei

As an informal example, Moens & Steedman cite the case of "climbing Mt Everest". The culmination of this event would be reaching the top of Mt. Everest. The preparatory process would consist of a number of discrete steps such as climbing, resting, and having lunch; and the consequent state would be characterized by the climbers being on top of the mountain.

5.2. Aside: Scripts, Plans, and Generalized Activities

Bundles of information related to actions have long been used in work in planning (see, for example, [Rich, 1983], chapter 8). The structure of Moens & Steedman's "elementary contingency-based events" seems isomorphic to the structure of a plan, and Moens & Steedman's relation of contingency between events, a "weak causal relation", seems similar to connectedness between steps in a plan.

As an example, consider a traditional plan constructed from STRIPS operators. An example such an operator, the operator `Pickup` for picking up an object in the blocks world, is shown in figure 3 (adapted from [Rich, 1983]).

Pickup(x)

Precondition:	**OnTable(x),**	**HandEmpty,**	**Clear (x)**
Delete List:	**OnTable (x) ,**	**HandEmpty,**	**Clear (x)**
Add List:	**Holding (x)**		

Figure 3: STRIPS operator Pickup

Consider the activity of "stacking two, blocks in the blocks world". The steps involved in this activity include picking up blocks, putting them down, and moving the hand around. The climax or culmination of this activity refers to the actual stacking of the two blocks; and the consequent state is characterized primarily by the fact that the two blocks arc now stacked on top of each other.

This might sound trivial at first, but it provides an interesting connection between aspectual composition and planning:

- Moens & Steedman's preparatory process corresponds to the collection of steps in the plan.
- The culmination takes place when the last step is completed, and the entire plan has been carried out.
- The consequent state can be computed by composing the add and delete actions of the operators involved. It corresponds to all the assertions that hold after the last step in the plan, and that are a result of the actions in the plan.
- The overall nucleus can be identified with the goal of the plan. That is, Moens & Steedman's nucleus for climbing Mt. Everest would correspond to a plan for climbing Mt. Everest.

In contrast to the blocks world, in the real world the distinction between primitive operators and sequences of steps lies entirely in the eye of the beholder. That is, any activity can be regarded as a single, primitive step, or as a complex activity in its own right. For example, the activity of picking up a block could be regarded as a primitive operation, but it could also be broken into a number of smaller operations of moving the robot arm around. This works the other way, too: An activity like "building an arch" is usually regarded as the subject of a complex plan, but a primitive that accomplishes this goal could be used just as well.

For the latter, "Scripts" have been proposed as a representation of the pertinent information. Again, there is an overall activity (e.g. eating in a restaurant), a series of steps, and certain results that characterize the consequent state; see figure 4 for an example.

By now, the similarity between these different structures might have become clearer. In our analysis, we will use a generic structure called a "generalized activity" that can be thought of as a partially instantiated plan.

The problem of plan recognition in language understanding is very difficult, and a solution for it is not assumed in this account of aspectual composition. To illustrate this point, consider the following sentence:

(30) Sandy is building a house.

The underlying "generalized activity" referred to by this sentence is one with the goal of building a house. Furthermore, the structure of this activity is like that of a plan. In particular, the activity involves a number

Restaurant Script

Roles:	**Customer, Waiter, etc.**
Entry Condition:	**Customer is hungry, customer has money**
Results:	**Customer has less money, customer is not hungry, etc.**
Steps:	**Customer enters**
	Customer orders
	Customer eats
	Customer leaves

Figure 4: A script

of steps. However, we do *not* assume that it can be inferred what exactly the individual steps are - only the structure of the activity is known. For the purpose of illustration, one possible instantiated activity is shown below in figure 5.

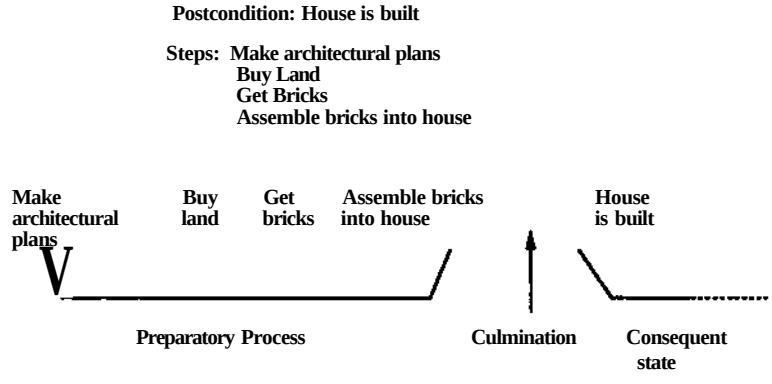


Figure 5: Instance of a generalized activity for aspectual composition

There are many questions related to this plan analogy that remain open. First, all the problems related to using a system of primitives apply:

- **What are the total available primitives?**
- **What are the primitive operators for a given activity, e.g. "building a house"?**
- **How is the grain size of the primitives chosen for a given plan?**

It is possible that answers to some of these questions could be obtained empirically. For example, perhaps a somewhat stable set of primitives for the house-building activity could be obtained by asking a sufficiently large number of people the following questions: What are the sub-activities involved in building a house? The question of chosing the appropriate grain size in context is more difficult, and no solution is in sight.

A second shortcoming of the approach outlined above arises because our plans are linear. That is, the steps that make our plans are arranged in a linear order. Non-linear planning (which originated with

[Sacerdoti, 1977]) could be adopted, imposing only partial orders on the steps in a plan. This would leave us with the problem of unifying partial orders, which has been discussed by [Reape, 1989].

Linearized preparatory processes will be assumed for this analysis. We can now see how Vendler-classes resemble parts of generalized activities:

- **Process:** (Part of) the collection of steps that make up a generalized activity.
- **Event:** Activity. Note that each step of an activity can be viewed as an activity in itself.
- **State:** Pre or post-conditions of an activity.
- **Culmination:** Change of state wheh an activity is finished, i.e. when all the steps have been taken.

5.3. Type Selection and Type-changing Operators

For aspectual composition, generalized activities as shown in figure 5 are assumed. The operators listed below manipulate parts of these activities, many of which are similar to operators discussed by [Moens and Steedman, 1988].

- **Iteration.** This constructs a complex event that consists of repeated generalized activities. Little or no emphasis is placed on the nature of the preparatory process or the nature of the consequent state of the repeated activities; the important point is that a culmination occurs over and over.
- **Deleting Culmination.** From a complete generalized activity, this operator strips off the culmination and retains only a part of the preparatory process. Note that the resulting process must start at the beginning of the preparatory process, but must end before the culmination occurs.
- **T^eat generalized activity as culmination.** This shift in point of view ("zooming out") results in a point activity that does not extend in time.
- **TVeat culmination as generalized activity.** This shift in point of view ("zooming in") results in a generalized activity that extends over time, and that has constituents (e.g. steps in the preparatory process) that are available to be picked out (e.g. by temporal reference).
- **TVeat generalized activity as a state.** This operator deletes the preparatory process, and returns the state that holds after the culmination.

The grammar fragment below includes type-changing operators written in a unification-based formalism that implement some of these operations.

5.4. Aspectual Feature System

In our grammar fragment, states will be disregarded. Furthermore, we will not distinguish between agentive and non-agentive eventualities because this distinction does not seem to influence aspectual composition.[3] Thus, as suggested by Marc Moens (p.c), two features are used to generate the aspectual types: durative and conclusive. The resulting lattice is shown in figure 6.

[3]**Agentivity does, however; influence co-occurrence with certain expressions (cf. Vendler's CTC), which is probably why it was confused with diagnostics for aspectual classes.**

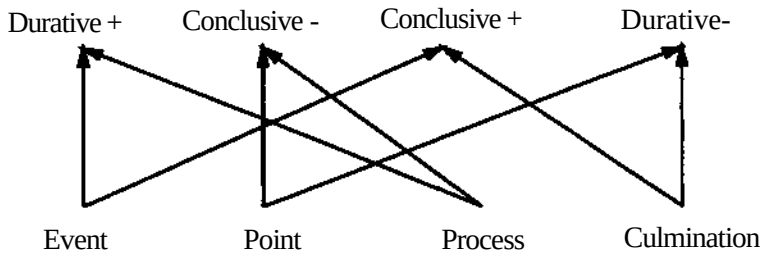


Figure 6: Aspectual type lattice

A feature structure type called *aspect* will be used to represent aspectual type; see figure 7. We have argued throughout that the aspectual information is semantic in nature; therefore, the aspectual infonnation should be located inside the value of the SEMANTICSICONTENT path. The value of this path is typed to *eventuality;* this is also shown in figure 7.

aspect
DURATIVE: *boolean*
CONCLUSIVE: *boolean*

eventuality
RELATION: *relation*
ASPECT: *aspect*
ARG1: *index*
ARG2: *index*
⋮

Figure 7: Feature structure types *aspect* and *eventuality*

5.5. On Cross-linguistic Validity

Having presented the outline of our analysis of aspect, we must ask about the cross-linguistic validity of this approach. This question can be answered in two parts. The first part concerns the details of our analysis, while the second part concerns the more general nature of our approach.

Our aspectual features and the typology of eventualities that is generated necessarily reflects an "English", or perhaps "Indo-european" perception of eventualities. To illustrate this point, consider the Japanese aspectual moipheme *te-iru* (example taken from [Hayashi, 1989]:

(31) a. Tanaka san wa sake o nomimashita.
b. Tanaka san wa sake o nonde-iru.

The first sentence includes the simple past form of the verb *nomu,* "to drink". The second sentence includes the *te-iru* form of this verb, i.e. *nomu* combined with the *te-iru* aspectual morpheme. Assuming the English aspectual typology, the sentence with *nonde-iru* has two possible readings:

(32) a. Mr. Tanaka is drinking sake,
b. Mr. Tanaka has drunk sake.

Such a state of affairs seems quite unlikely, - especially since Japanese speakers do not consider there to be ambiguous readings for sentences with *te-iru:*

> "To native speakers of English and other standard European languages, this may appear to be a puzzling combination, but Japanese speakers are often equally puzzled that anyone should see more than meaning in the various senses of *te-iru*." [Jacobson, 1982]

Instead, it seems that Japanese speakers employ different aspectual classes, which could be generated by a different set of aspectual features. On this count, then, our analysis is probably limited to languages that employ "English" Metaphysics [Bach, 1981], widespread as that view of the world may be.

On the second, far more significant count, however, our analysis retains some cross-linguistic validity. The mechanism employed — selection for aspectual type coupled, base readings for verbs, and type-changing operators that operate over a set of structured activities — is general enough to capture any aspectual typology. Bach drew the following conclusion about different metaphysical assumptions:

> "The Hopi and English world views are not at bottom incompatible, but rather different orchestrations of material that is part of our common human heritage." [Bach, 1981], p. 64

We might paraphrase this as saying that the English and Japanese aspectual systems are merely different orchestrations of the common linguistic aspectual composition mechanisms. The rest of this paper will be devoted to a technical exposition of the details of these mechanisms, along with examples drawn from English.

6. Introduction to HPSG

We will assume the HPSG framework [Pollard and Sag, 1987; Pollard and Sag, forthcoming] for the grammar fragment. (See also [Franz, 1990] for a brief summary of HPSG.) Some relevant properties of this framework are summarized below.

6.1. Components of an HPSG Grammar

HPSG is an *axiomatic* theory of grammar, because the lexical entries, ID schemata, LP constraints, and general principles represent constraints on well-formed sorted (typed) feature structures. Sorted feature structures are used to model linguistic objects. As an example, Figure 8 contains a diagram of the (simplified) feature structure that is used to model the verb *laughs*. Note that lexical entries for verbs are similar to noun entries, which facilitates handling nominalization.

We will assume that the universal principles of HPSG hold, and will concentrate on those aspects that are particular to aspectual composition. Technically, a grammar in the framework of HPSG consists of four components:

- **Signature.** Four kinds of information are specified in the signature:
  - The available sorts, features, and relations.
  - The subsumption ordering on the sorts.
  - Which features are carried by the individual sorts and relations ("feature appropriateness").

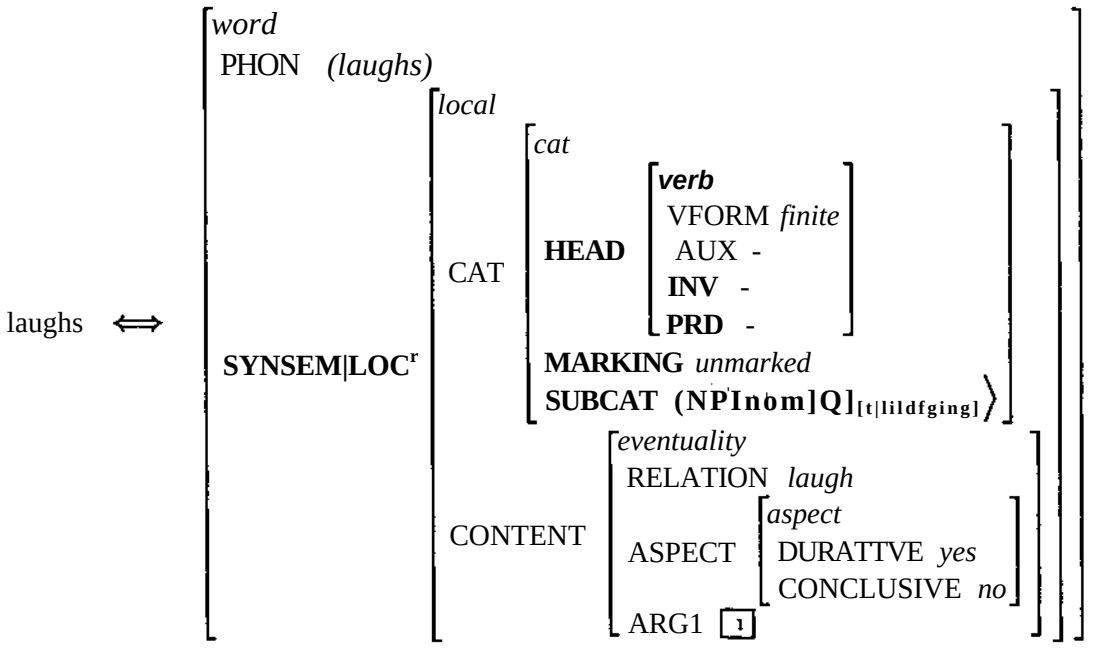


Figure 8: Lexical entry for *laughs*

- Type restrictions on the values of individual features ("sortal restrictions") and on the arguments of relations.

- **Lexicon.** The lexicon is the repository of all information carried by lexical sorts.

- **Principles of Grammar.** Universal well-formedness conditions such as the Head Feature Principle and the Subcategorization principle.

- **Constituent Structure Principles.** Well-formedness conditions on phrases related to constituent structure. This includes the Immediate Dominance Principle (IDP), and the Constituent Order Principle (COP).

6.2. The Sort Hierarchy

HPSG uses sorted feature structures to represent the information that is contained in linguistic expressions. The type scheme for feature structures is established by the signature. Below is an excerpt from a signature for an HPSG fragment for English; figure 10 shows the sub-hierarchy for English constituent structure.

The sign _L stands for "bottom", a special sort carrying no information that always forms the lowest element in the sort hierarchy. It has two immediate subsorts *sign* and *synsem; sign* itself has two further subsoils *word* and *phrase.*

Sorts are arranged in an inheritance hierarchy. Since sorts inherit information from their supersorts, *word* and *phrase* inherit appropriateness constraints from *sign.* In particular, the full record entry for *phrase* would be the following:

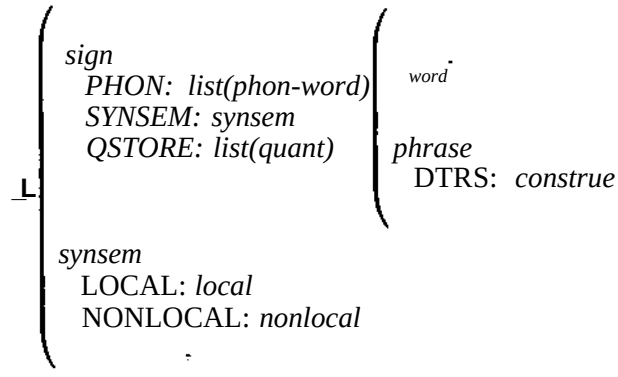


Figure 9: Partial sort signature for English

6.3. Principles of Grammar

Linguistic signs are well-formed if they obey all principles of grammar, where this notion of "principle" subsumes grammar "rules". A number of principles governing phrases have been proposed in HPSG:

- **Head Feature Principle.** The HEAD value of a headed phrase is unified with the HEAD value of the head daughter.
- **Subcategorization Principle.** The SUBCAT value of the head daughter in a headed phrase is the concatenation of the phrase's SUBCAT list with the list of SYNSEM values of the complement daughters. Items on the SUBCAT list are ordered by increasing obliqueness.
- **Semantics Principle.** The CONT value of a phrase is unified with that of the head daughter.
- **SPEC Principle.** A non-head daughter's SPEC value, if it exists, is unified with the SYNSEM value of the head daughter.
- **Quantifier Inheritance Principle.** The QSTORE value of a phrase is the union of the QSTORE values of the daughters less those quantifiers that are retrieved at that phrase.
- **NONLOCAL Feature Principle.** The INHERITED value of each nonlocal feature on a phrase is the union of the INHERITED values on the daughters minus the TO-BIND values on the head daughter.

6.4. Phrase Structure Principle

Two additional principles are related to phrase structure. Below are their informal specifications for the case of English:

- **Immediate Dominance Principle.** This principle specifies disjunctively what kinds of constituent structures are available for well-formed phrases:
  1. A saturated (empty SUBCAT list), uninverted phrase (bearing MARKING: *unmarked)* with DTRS value of sort *head-comp-struc,* a phrasal sign as HEAD-DTR, and only one COMP-DTR.

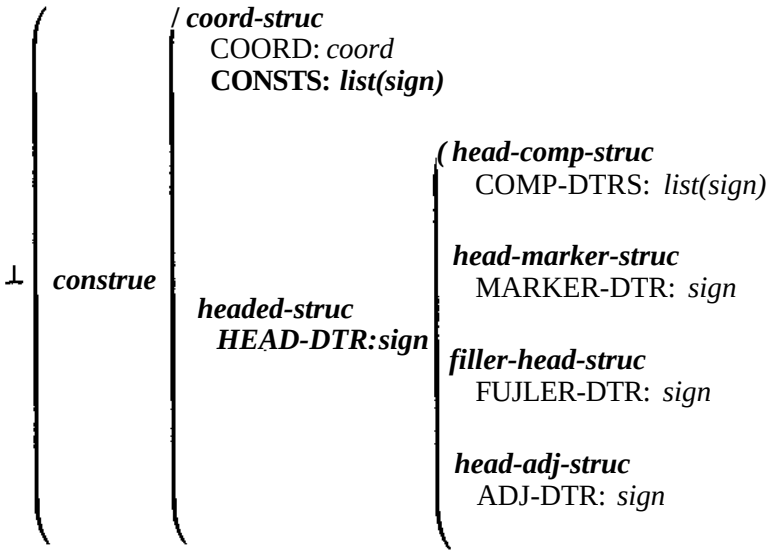


Figure 10: Sort hierarchy for English constituent structure

phrase
PHON: ***list(phon-word)***
SYNSEM: *synsem*
QSTORE: ***list(quant)***
DTRS: ***construe***

Figure 11: Feature structure sort *phrase*

2. An uninverted phrase (bearing MARKING: *unmarked)* with one item on the SUBCAT list with DTRS value of sort *head-comp-struc,* and a lexical sign as HEAD-DTR.
3. A saturated, inverted phrase (bearing MARKING: *unmarked)* with DTRS value of sort *head-comp-struc,* and a lexical sign as HEAD-DTR value.
4. A phrase with DTRS value of sort *head-marker-struc* whose MARKER-DTR is a maiker. The MARKER-DTR has its SPEC value unified with the SYNSEM value of the head daughter, and its MARKING value unified with that of the mother.
5. A phrase (bearing MARKING: *unmarked)* with DTRS value of sort *head-adj-struc.* The MOD value of the ADJ-DTR is unified with the SYNSEM value of the head daughter.

- **Constituent Order Principle.** This Principle specifies the relation between the PHON value of a phrase, and those of the phrase's daughters. It is usually stated in terms of a number of Linear Precedence (LP) constraints.

As an example of a (non-disjunctive) principle of grammar, figure 12 shows the first of HPSG's ID schemata for English described above.

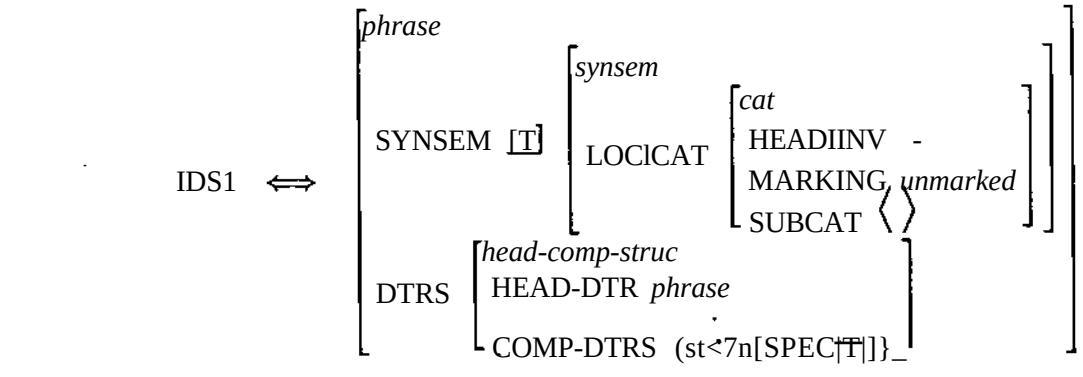


Figure 12: ID schema 1

7. Weak Type Coercion

In this section, we present the details of our approach to aspectual composition. The overall scheme is as follows:

1. The semantic values of VPs and sentences (the value of the SYNSEM|LOC|CONTENT path) are types of *eventualities* that refer to parts of generalized activities.
2. Eventualities have an ASPECT feature, whose value specifies the aspectual type of the eventuality.
3. Linguistic expressions that contribute to aspectual composition, such as aspectual adverbials, select for eventualities of a certain aspectual type.
4. Aspectual composition operators, such as iteration, stripping-off culmination, etc., are functions from eventualities to eventualities that change both the RELATION and ASPECT value of the eventuality.
5. Aspectual "weak type coercion" occurs by the application of a composition operator in order to meet the selectional restriction of a complement or modifier that takes part in aspectual composition.

7.1. Some Properties of Weak Type Coercion

One of the immediate consequences of this approach is that an infinity of aspectual interpretations is predicted for every sentence. This holds even in the absence of any modifiers, since the type-changing operators are free to apply as long as there is a match in aspectual type.

We believe that this is the right prediction for a *competence* theory of aspectual composition. By constructing complicated examples, the reader may convince himself that it is indeed necessary to allow all possible coercion paths. Consider, for example, the following instance of intra-sentential aspectual coercion:

(33) a. John ran.
b. He reached the store in just 14 minutes.

This example shows that the space of possible aspectual interpretations is unbounded, since aspectual type coercion occurs across sentences.

A different argument against our approach might point out the lack of empirical justification for predicting infinite numbers of aspectual interpretations. Although this is probably a valid point, our theory does not need to address it. To see why, it is useful to draw an analogy with syntactic theory and the phenomenon of center-embedding. Even though it is clear that in language use the levels of center-embedding are sharply limited, it is usually acknowledged that syntactic theory studies the logical character of grammatical competence, and that a different component of a theory of language use would address limits on center-embedding and the like. In the same vein, we are not concerned about keeping the number of predicted aspectual analyses to some bound within our competence theory.

A further point to note is that the underlying mechanism proposed here seems to be generally useful. In particular, consider the notions of "packaging" and "grinding" (cf. [Bach, 1986]). A count noun can be "ground" into a mass term:

(34) a. Kim bought ten carrots, (count)
b. There is too much carrot in this cake, (ground into mass)

Similarly, a mass term can be packaged into a count term:

(35) a. Sandy likes coffee, (mass)
b. This restaurant serves an international selection of teas and coffees, (packaged into count)

It seems that our analysis applies directly to the phenomena of packaging and grinding. There are base readings for different terms — count for carrots, mass for coffee. In addition, there are type-changing operators that perform packaging and grinding. These operators can apply freely to produce mass or count entities. The application of these operators produces nominal entities of the appropriate mass/count type, given the selectional restrictions imposed by context.

7.2. Ambiguity in Weak Type Coercion

The mechanism used for aspectual composition has been termed *weak* type coercion because there is no direct connection between the application of type-changing operators and selection for certain aspectual types. Thus, when certain expressions or morphemes select for a certain aspectual type, any number or combination of operators could apply to produce the selected type.

For example, we might say that the progressive morpheme selects for [DURATIVE +]. If the progressive morpheme is combined with a V that is [DURATIVE -], two different operators could apply to produce a match: Iteration and zooming in to activity. A number of factors determine the preferred reading for individual verbs. Compare, for example, the following sentences:

(36) a. John was winning the race, (zooming in)
b. John was hiccuping. (iteration)
c. John played the sonata for a minute, (focus on preparatory process)
d. John played the sonata all day. (iteration)

Which operators are chosen seems to depend to a large extent on world knowledge about the activities, how long they take, their significance, etc. Again, we do not think it is necessary to spell out these factors, since we are focusing on the logical constraints that shape the aspectual composition process.[4]

[4]**Since there is no generally accepted methodology for tasks of this kind, the magnitude of this enterprise should not be underestimated.**

This sort of ambiguity in aspectual interpretation is also evident with adverbs like *almost.* Consider the following sentence:

(37) John almost ran ten miles.

There are two distinct readings for this sentence:

(38) a. Kim entered the race, but he pulled a muscle during practice and couldn't run.
b. He almost ran ten miles.

(39) a. Sandy was doing very well, but he had to give up after eight miles,
b. He almost ran ten miles.

In the first inteipretation, the eventuality under the scope of *almost* is the entire event. In the second interpretation, it is only the culmination - finishing the ten miles - that falls under the scope of *almost.* Again, this sort of ambiguity arising from type coercion is predicted by the analysis.

73. Limits of Weak Type Coercion

In this section, we will briefly discuss some phenomena that are beyond the scope of this analysis. First, a class of adverbs and modifiers that play a more active role in aspectual composition will be examined.

Consider the following examples:

(40) a. Sandy frequently runs a mile.
b. Chris went to the store three times.

Adverbs and other modifiers of this type are not covered by our analysis, because they do more work than mere selection for a certain aspectual type. Modifiers of this type construct a new relation; *three times,* for example, constructs an iteration where the iterated culmination occurs exactly three times. The crucial point is that in our analysis, selection for aspectual type is performed by enforcing agreement between the modifier and the syntactic head. This scheme breaks down with "active" modifiers like *three times.* There is a remedy for this problem, however. We can add further operators to our inventory of type-changing operators that are more closely tied to the actual modifiers. For example, a more elaborate iteration operator could be added for modifiers like *three times* which would construct an iteration-event with a specified number of iterations.

Below is another example that is not covered by the analysis.

(41) Kim left the room for several minutes.

The literal meaning of this sentence might be as follows: Kim leaves the room. The consequent state is that Kim is outside the room. This consequent state holds for a few minutes. An implicature tells us that the state of Kim-being-outside only holds for as long as we were told about, and that after this period the default activity which negates the consequent state occurs. Thus, we infer that Kim re-enters the room after a few minutes.

Accounting for negation is very difficult, and we will not attempt to do so. Consider the following examples:

(42) a. Sandy didn't arrive until midnight,
b. Chris didn't win the race.

There are at least two methods to account for negated eventualities. The first is to assume that the aspectual type of a negation is a state. Then, the proper understanding of negated sentences would rest on an implicature. To take the first sentence, it asserts that the state held until midnight. The implicature is that the state ceased to hold at midnight, and the way the state is negated is by Sandy's arriving.

A second possibility is to treat negation as a special operator that induces ambiguity in aspectual interpretation, much like adverbs like *almost* (cf. section 7.2). Consider the second example above. The meaning of this sentence could be either of the following:

1. John ran in the race, but didn't win it. (negated culmination)
2. John didn't run in the race at all. (negated activity)

It is not clear which of these two options is preferable, and this question will be left open.

7.4. Feature Structure Representation of Generalized Activities

In the grammar fragment, generalized activities will be represented as feature structures. This is illustrated in figure 13. Activity feature structures have three attributes: A list of steps that make up the preparatory process, a culmination, and a set of conditions that hold in the consequent state. The culmination index is a semantic index that can be referred to as a "reference marker". Note that culmination indices carry a feature that contains a pointer back to the entire activity; this is essential for some of the aspectual composition operators.

$$\boxed{1}\begin{bmatrix} \textit{T?uilding-a-house} \\ \text{STEPS } \textit{list(activity)} \\ \text{™TT } \backslash\textit{*TM ATTHM } \backslash\textit{culmination-index} \\ \text{CULMINATION } [\text{CULMINATION.OF Q}] \\ \text{CONSEQUENCES } \{\text{ew«(finished-house)}\} \end{bmatrix}$$

Figure 13: FS representation for an instance of activity type "build a house"

7.5. Examples of Aspectual Composition

In section 5.3, the listed the operators for aspectual composition were listed. In this section, we will look at examples of the composition operators in action. The method used is as follows: First, the base reading for a given eventuality is shown. For example, the base reading for *build a house* is that of an event. Next, we will show sentences of the same clause in a context that selects for a different aspectual type. In such a context, the semantic value of the clause in question is coerced into a different aspectual type. The purpose of this is to illustrate the operators that take part in aspectual composition.

First, note that the **base reading** for "play a sonata" is an event.

(43) Kim played the sonata.

Next, an example of **deleting culmination**, which results in a process.

(44) Kim played the sonata for a few minutes.

For an example of a generalized activity that is treated as a **punctual culmination**:

(45) When Kim played the sonata, he received a standing ovation.

We will consider operators that apply to culminations or processes next. First, consider an instance of **iteration**. It applies to a culmination. Since the operators can be nested, the culmination that is iterated could be the base reading, or the result of some other aspectual composition operator. In the example shown here, the base reading is more likely to be that of an event:

(46) a. Sandy presented his paper on computational astrology.
b. Sandy presented his "computational astrology" paper for a few months, until everybody had heard it at least twice.

As an example of **treating culmination as an activity** or "zooming in", consider the following sentences.

(47) Chris reached the top.

The base reading for *reach the top* is as a culmination. Now, consider the following sentence:

(48) Chris reached the top in two hours.

The adverbial *in two hours* can only combine with a extended eventuality, so we zoom in on reaching-the-top and treat it as a generalized activity that is extended in time.

7.6. Type Selection

In the examples listed in the previous section, the semantic value of the following clauses were coerced to different aspectual types. (The tense will be omitted on these clauses, since the tense morphemes could act as aspectual coercion operators in themselves.)

(49) a. Kim play the sonata.
b. Sandy present his paper
c. Chris reach the top.

The following contexts were used that selected for semantic values of different aspectual types:

(50) a. Combination with *for a few minutes* adverbial.
b. Temporal reference to *receiving a standing ovation.*
c. Combination with *for a few months* adverbial.
d. Combination with *in two hours* adverbial.

"Weak type coercion" occurs as the interplay of type-changing operators and modifiers selecting for semantic values of a certain type. In particular, using the feature structure of type *aspect* introduced above, these items select for the following aspectual types:

(51)

a. Combination with *for an <time period>* adverbial selects for a process:

$$\begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATTVE } \textit{yes} \\ \text{CONCLUSIVE } \textit{no} \end{bmatrix}$$

b. Combination with *in an <time period>* adverbial selects for an event:

$$\begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATTVE } \textit{yes} \\ \text{CONCLUSIVE } \textit{yes} \end{bmatrix}$$

c. Temporal reference to *receiving a standing ovation* selects for a culmination:

$$\begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATTVE } \textit{no} \\ \text{CONCLUSIVE } \textit{yes} \end{bmatrix}$$

7.7. **Type-changing Operators**

The other half of weak type coercion is achieved by the aspectual composition operators. These operators change a semantic object into a new aspectual type. This is summarized in table 3 below:

Operator	**Type Change**
Iteration	$\begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATIVE } \textit{no} \\ \text{CONCLUSIVE } \textit{boolean} \end{bmatrix} \longrightarrow \begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATIVE } \textit{yes} \\ \text{CONCLUSIVE } \textit{no} \end{bmatrix}$
Deleting Culmination	$\begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATIVE } \textit{yes} \\ \text{CONCLUSIVE } \textit{yes} \end{bmatrix} \longrightarrow \begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATIVE } \textit{yes} \\ \text{CONCLUSIVE } \textit{no} \end{bmatrix}$
Zooming in on Culmination	$\begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATIVE } \textit{yes} \\ \text{CONCLUSIVE } \textit{yes} \end{bmatrix} \longrightarrow \begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATIVE } \textit{no} \\ \text{CONCLUSIVE } \textit{yes} \end{bmatrix}$
Zooming out to Activity	$\begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATIVE } \textit{no} \\ \text{CONCLUSIVE } \textit{yes} \end{bmatrix} \longrightarrow \begin{bmatrix} \textbf{\textit{aspect}} \\ \text{DURATIVE } \textit{yes} \\ \text{CONCLUSIVE } \textit{yes} \end{bmatrix}$

Table 3: Type changes from operators

These operators work over generalized activities. Since it is not the case that the entire activity (including all the steps in the preparatory process, etc.) can be inferred right away, underspecification is used. It is not necessary to assume an "instantiated" activity like the one shown in figure 13 above, since only the structure of the activity is necessary. Thus, the aspectual composition operators can operate over the "shell"

of an activity , as shown in figure 14. This diagram includes structure-sharing tags to indicate the places that operators will dereference and point to.

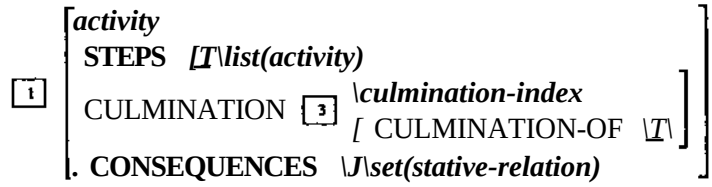


Figure 14: Uninstantiated *generalized activity* feature structure

Conceptually, the type-changing operators are unary rules that can apply freely to feature structures of sort *phrase.* In terms of an HPSG grammar as a set of constraints, this scheme can be conceptualized in the following way: If a feature structure A of type *phrase* satisfies all the constraints in a Grammar G, then the result O(A) of applying an aspectual operator O to A is also licensed by the grammar. The operators are shown as unary rules with structure-sharing tags in figures 15-18.

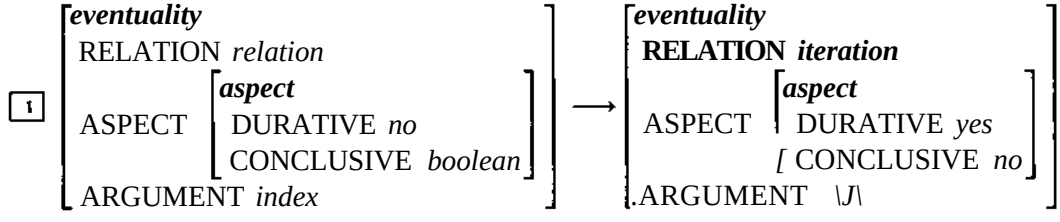


Figure 15: "Iteration" operator for aspectual composition

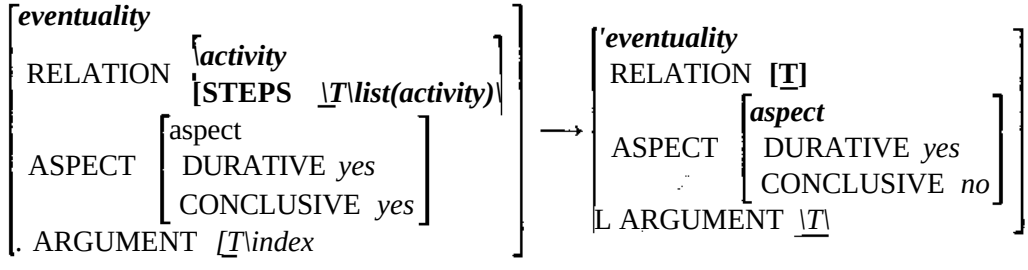


Figure 16: "Deleting culmination" operator for aspectual composition

8. Grammar Fragment: Rules and Lexical Entries

The previous section explained the mechanisms of selection for a specified aspectual type, and free application of type-changing operators. This section includes grammar rules and lexical entries for PP-adverbials and adverbs. Taken together, these two parts constitute an HPSG grammar fragment that accounts for aspectual composition for these cases.

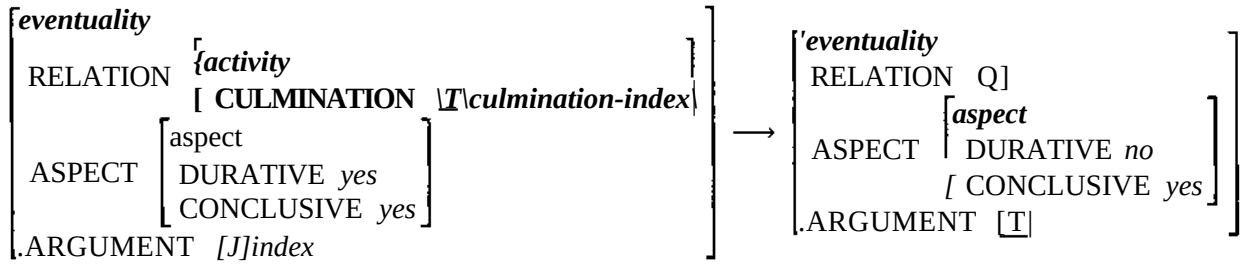


Figure 17: "Zooming in on culmination" operator for aspectual composition

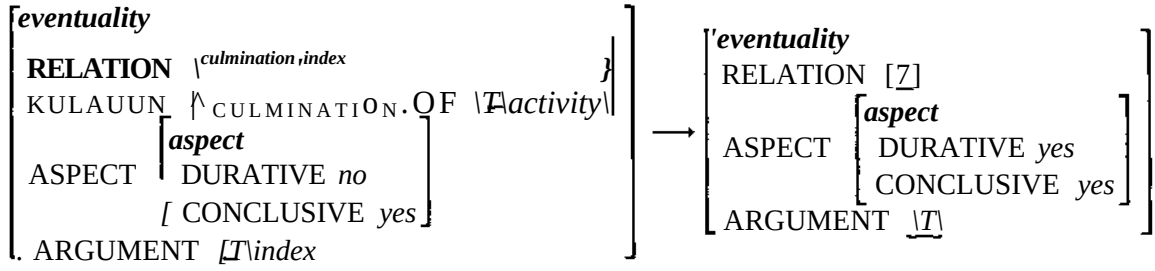


Figure 18: "Zooming out to activity" operator for aspectual composition

The grammar fragment is extensible, because all the necessary machinery for aspectual composition has been introduced. Additional types of aspectual adverbials could be covered by introducing additional grammar rules for the new constructions, and additional lexical entries for the relevant adverbial heads.

8.1. Prepositional Adverbials

The first case to be examined concerns prepositional aspectual adverbials; that is, prepositional phrases that play the role of aspectual adverbials. We will assume that general principles of grammar have an effect equivalent to a syntactic rule for combining a sentence with a PP:

VP ⟶ VP PP

Below, this rule is shown as an annotated phrase structure rule. Note that this is merely a notational variant of the usual HPSG notation of principles of grammar as feature structures.

For the purpose of this analysis, we will assume that adverbials subcategorize for phrasal projections of V (which, in HPSG, includes sentences). Thus, in the rule above the PP is the semantic head. The lexical entry for the preposition includes a specification of the aspectual type to which the preposition can attach; this is shown in the next section. Aspectual type-changing operators can apply freely to change the type of the original VP; if a match in aspectual type obtains, the structure will obey the constraints of the grammar.

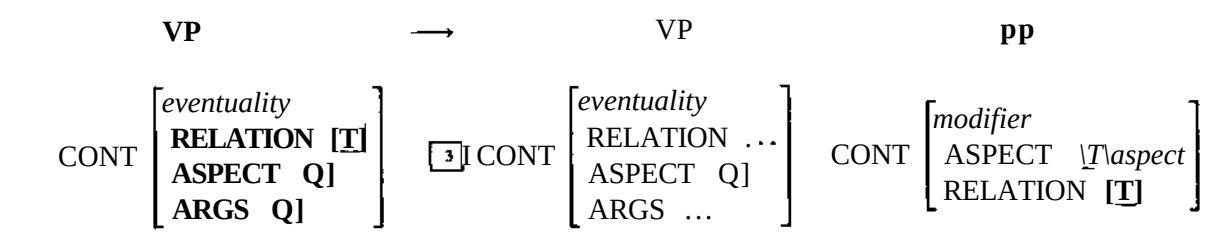


Figure 19: Annotated VP —• VP **PP** rule

8.2. Lexical Entries for Aspectual Prepositions

The prepositions *in* and *for* are semantically ambiguous. Here, we are only interested in the "aspectual" senses. (Other senses for *for* include "purpose" or "benefactor", and for *in* "location".) The "aspectual" senses for the two prepositions *in and for* are shown in figure 20. The two lexical entries reflect the fact that *for* selects for a process, while *in* semantically selects for an event

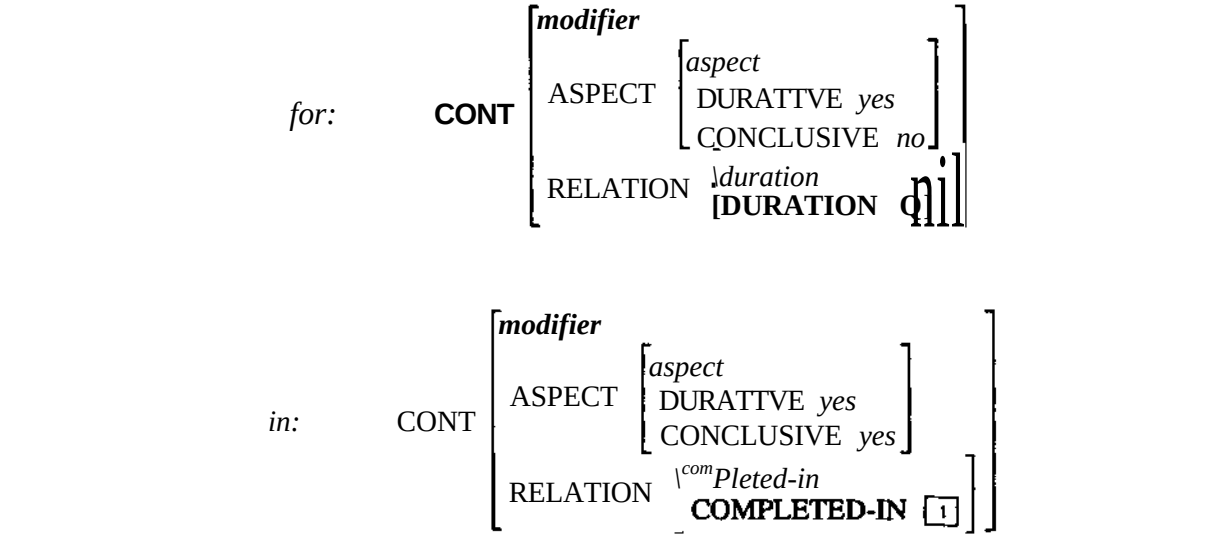


Figure 20: Lexical entries for *for* and *in*

8.3. **Example:** *in an hour*

Consider an example to illustrate how the aspectual composition scheme works.

(52) a. Kim reached the top.
b. Kim reached the top in an hour.

The reading for the first sentence is of aspectual type culmination, since that is the base type for *reach the top:*

$$\begin{bmatrix} \textit{aspect} \\ \text{DURATIVE } \textit{no} \\ \text{CONCLUSIVE } \textit{yes} \end{bmatrix}$$

The second sentence includes the sentential PP *in an hour.* As shown in the (partial) lexical entry for *in* above, this preposition selects for a sentence whose semantics has the following aspectual type:

$$\begin{bmatrix} \textit{aspect} \\ \text{DURATTVE } \textit{yes} \\ \text{CONCLUSIVE } \textit{yes} \end{bmatrix}$$

If the S —• S PP rule was applied at this point, it would fail because of the structure-sharing constraint on the ASPECT values. The aspectual type of *Kim reached the top* matches the "zooming out to activity" type-changing operator, and so the operator applies. The outcome is twofold. First, the resulting aspectual type matches that selected by *in,* so the derivation can proceed. Second, the semantic value of the sentence has changed from a *culmination-index* to an *activity,* making all constituents of the activity of reaching-the-top accessible for further interpretation.

8.4. Aspectual Adverbs

Next, consider adverbs. Again, we assume principles with an effect equivalent to a syntactic rule for combining a sentence with an adverb:

S ⟶ S **Adv**

This rule is shown with the relevant annotations below. Note that the adverb takes scope over the verbal semantics.

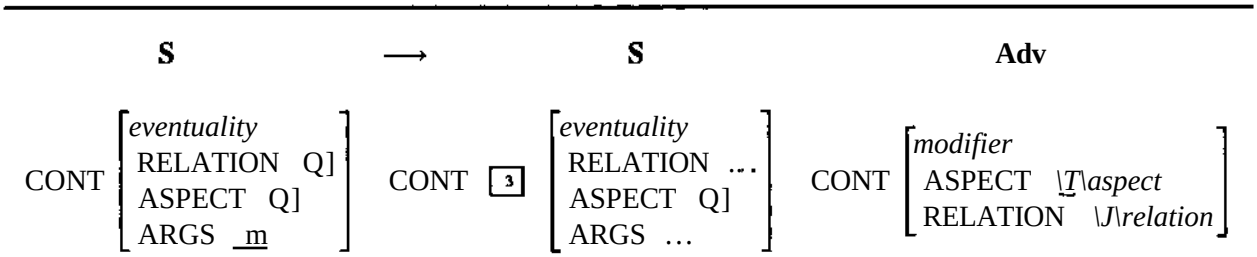


Figure 21: Annotated S —> S **Adv** rule

For the puipose of this analysis, we will assume that adverbials subcategorize for phrasal projections of V (which, in HPSG, includes sentences). Thus, in the rule above the PP is the semantic head.

As with the prepositional modifiers, the adverb is the semantic head of this construction, and it selects for a verbal projection of the specified aspectual type.

8.5. Lexical Entries for Aspectual Adverbs

Two adverbs will be taken as examples: *frequently* and *slowly, frequently* is taken to select for a non-durative expression, while *slowly* selects for a durative expression. The two lexical entries are shown in figure 22. Note how the lexical entries are underspecified (using the sort *boolean)* with respect to whether the meaning of the sentence has a culmination.

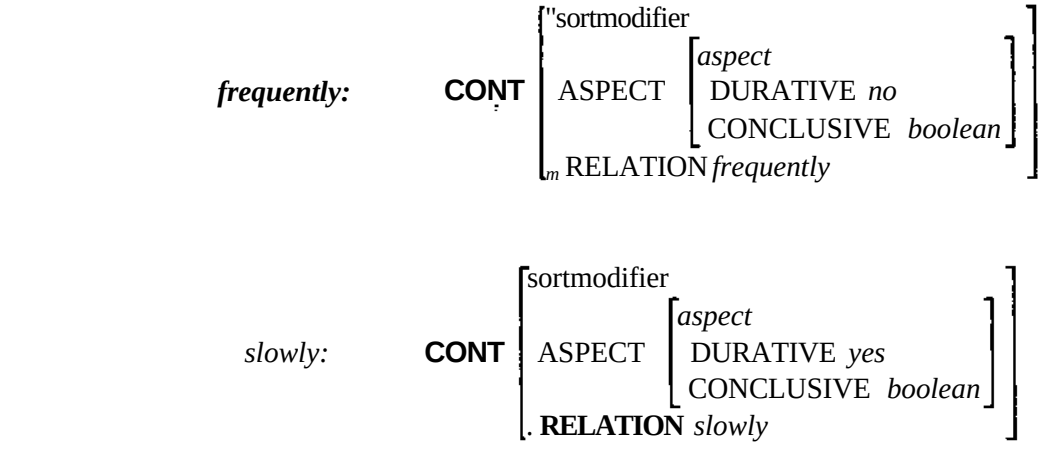


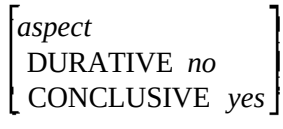
Figure 22: Lexical entries for *frequently* and *slowly*

8.6. Example: *slowly*

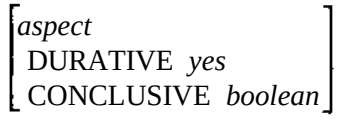
Consider an example with the adverb *slowly.*

(53) a. Sandy crossed the finishing line.
b. Sandy crossed the finishing line slowly.

The reading for the first sentence is of aspectual type culmination, since that is the base type for *cross the finishing line:*



The second sentence includes the sentential adverb *slowly.* This adverb selects for a sentence whose meaning has the following aspectual type:



If the S —• S **Adv** rule was tried at this point, it would fail because of the structure-sharing constraint on the ASPECT values. As in the last example, the aspectual type *of Kim crossed the finishing line* matches

the "zooming out to activity" type-changing operator. The adverb selects for a CONCLUSIVE value of type *boolean;* since this sort subsumes (is below in the sort hierarchy) the sort *yes,* the operator can apply. As a result, the resulting aspectual type matches that selected by *slowly,* so the derivation can proceed.

9. Conclusions

We have shown that there are problems with a static, lexically-specified account of aspectual type. Instead, we have proposed a method of aspectual composition where the aspectual type of eventualities is derived from the weak coercive interplay of adverbials' selection for certain aspectual type, and the free application of type-changing operators.

There are many parallels between this work and the proposals outlined in [Boguraev and Pustejovsky, 1990]. At a somewhat abstract level, both approaches share the underlying philosophy of replacing a static, a-priori defined set of lexical meanings with dynamic processes that rely on knowledge representation techniques. In our analysis, we have shown some interesting connections to work in planning, and we have chosen the HPSG framework for its formal rigor, clarity, and precision.

It should be noted that the aim of this paper is to explicate the logical structure of aspectual composition, and not to give a performance account of e.g. actual operator application. Our system of weak type coercion expresses the constraints on aspectual composition. Thus, it defines the space of possible semantic and aspectual analysis of natural language expressions. Our system could be extended to such a performance account by adding processing heuristics that specify the order in which this space is to be searched, and we believe this to be a perfectly feasible extension that may be addressed in the future.

Acknowledgements

I would like to thank Bob Carpenter, Marc Moens, David Evans, Lori Levin^ Brad Pritchett, and Nicholas Brownlow.

References

[Bach, 1981] Bach, E. (1981). On time, tense, and aspect: An essay in English metaphysics. In Cole, P., editor, *Radical Pragmatics*, pages 62–81, New York. Academic Press.

[Bach, 1986] Bach, E. (1986). The algebra of events. *Linguistics and Philosophy*, 9:5–16.

[Barwise, 1981] Barwise, J. (1981). The situation in logic. *Journal of Philosophy*, 7(78):369–397.

[Boguraev and Pustejovsky, 1990] Boguraev, B. and Pustejovsky, J. (1990). Lexcial ambiguity and the role of knowledge representation in lexicon design. In *COLING-90*, pages 36–41.

[Carpenter, 1989] Carpenter, R. (1989). *Phrase Meaning and Categorial Grammar*. PhD thesis, University of Edinburgh.

[Dahl, 1981] Dahl, Ö. (1981). On the definition of the telic-atelic (bounded-unbounded) distinction. In Tedeschi, P. and Zaenen, A., editors, *Syntax and Semantics: volume 14, Tense and Aspect*, pages 79–91, New York. Academic Press.

[Davidson, 1967] Davidson, D. (1967). The logical form of action sentences. In Rescher, N., editor, *The Logic of Decision and Action*, Pittsburgh, PA. University of Pittsburgh Press.

[Dowty, 1979] Dowty, D. (1979). *Word Meaning and Montague Grammar*. D. Reidel, Boston, MA.

[Dowty et al., 1981] Dowty, D., Wall, R., and Peters, S. (1981). *Introduction to Montague Semantics*. D. Reidel, Dordrecht.

[Franz, 1990] Franz, A. (1990). A parser for HPSG. Report CMU-LCL-90-3, Laboratory for Computational Linguistics, Carnegie Mellon University, Pittsburgh, PA.

[Hayashi, 1989] Hayashi, M. (1989). A verb classification scheme and the *te-iru* form of verbs in Japanese. Department of General Linguistics, University of Pittsburgh.

[Hendler et al., 1990] Hendler, J., Tate, A., and Drummond, M. (1990). AI planning: Systems and techniques. *AI Magazine*, pages 61–77.

[Jacobson, 1982] Jacobson, W. (1982). Vendler's verb classes and the aspectual character of japanes *te-iru*. In *Proccedings of the 8th annual meeting of the Berkley Linguistic Society*.

[Johnson, 1981] Johnson, M. (1981). A unified temporal theory of tense and aspect. In Tedeschi, P. and Zaenen, A., editors, *Syntax and Semantics: volume 14, Tense and Aspect*, pages 145–175, New York. Academic Press.

[Kenny, 1963] Kenny, A. (1963). *Action, Emotion, and Will*. Humanities Press, New York.

[Lys, 1988] Lys, F. (1988). *An Analysis of Aspectual Compositionality*. PhD thesis, Northwestern University.

[Moens and Steedman, 1988] Moens, M. and Steedman, M. (1988). Temporal ontology and temporal reference. *Computational Linguistics*, 14(2):15–28.

[Mourelatos, 1981] Mourelatos, A. (1981). Events, processes, and states. InTedeschi, P. and Zaenen, A., editors, *Syntax and Semantics: volume 14, Tense and Aspect,* pages 191-212, New York. Academic Press.

[Nirenburg and Pustejovsky, 1988] Nirenbuig, S. and Pustejovsky, J. (1988). Processing aspectual semantics. In *Proceedings of the Cognitive Science Conference,* pages 658-665.

[Parsons, 1985] Parsons, T. (1985). Underlying events in the logical analysis of English. In LePore and Mclaughlin, editors, *Actions and Events: Perspectives on the Philosophy of Donald Davidson,* Oxford. Blackwell.

[Parsons, 1989] Parsons, T. (1989). The progressive in english: Events, states, and processes. *Linguistics and Philosophy,* 12:213-241.

[Partee, 1984] Partee, B. (1984). Nominal and temporal anaphora. *Linguistics and Philosophy,!*:243-286.

[Pelletier and Schubert, 1987] Pelletier, F. J. and Schubert, L. K. (1987). Three papers on the logical form of mass terms, generics, base plurals, and habituals. Technical Report TR 87-3, Depatment of Computing Science, University of Alberta, Edmonton, Alberta, Canada.

[Pollard and Sag, 1987] Pollard, C and Sag, I. (1987). *Information-Based Syntax and Semantics: Volume 1, Fundamentals,* volume 13 of *CSU Lecture Series.* CSLI, Stanford, CA.

[Pollard and Sag, minga] Pollard, C. and Sag, I. (forthcominga). Anaphors and the scope of Binding theory. *Linguistics and Philosophy.*

[Pollard and Sag, mingb] Pollard, C. and Sag, I. (forthcomingb). *Information-Based Syntax and Semantics: Volume 2.* CSLI Lecture Series. CSLI, Stanford, CA.

[Quirk et al., 1985] Quiik, R., Greenbaum, S., Leech, G., and jan Svartik (1985). *A Comprehensive Grammar of the English Language.* Longman, New York.

[Reape, 1989] Reape, M. (1989). A logical treatment of semi-free word order and bounded discontinuous constituency. In *EACL-89,* pages 103-110, Manchester, UK.

[Rich, 1983] Rich, E. (1983). *Artificial Intelligence.* McGraw Hill, Singapore.

[Sacerdoti, 1977] Sacerdoti, E. (1977). *A structure for plans and behavior.* American Elsevier, New York.

[Smith, 1981] Smith, C. (1981). Semantic and syntacic constraints on temporal interpretation. InTedeschi, P. and Zaenen, A., editors, *Syntax and Semantics: volume 14, Tense and Aspect,* pages 213-237, New York. Academic Press.

[Taylor, 1977] Taylor, B. (1977). Tense and continuity. *Linguistics and Philosophy,* 1:199-220.

[Thomason, 1974] Thomason, R. H., editor (1974). *Formal Philosophy: Selected Papers by Richard Montague,* New Haven. Yale University Press.

[Thomason and Stalnaker, 1973] Thomason, R. H. and Stalnaker, R. C. (1973). A semantic theory of adverbs. *Linguistic Inquiry,* pages 195-220.

[van Voorst, 1986] van Voorst, J. (1986). *Event Structure.* PhD thesis, University of Ottawa.

[Vendler, 1967] Vendler, Z. (1967). *Linguistics in Philosophy.* Cornell University Press, Ithaca, NY.

[Verkuyl, 1989] Verkuyl, H. J. (1989). Aspectual classes and aspectual composition. *Linguistics and Philosophy,* 12:39-94.

[Vlach, 1981] Vlach, F. (1981). The semantics of the progressive. In Tedeschi, P. and Zaenen, A., editors, *Syntax and Semantics: volume 14, Tense and Aspect,* pages 271-292, New York. Academic Press.