Chapter 10
Event Semantics

In all previous chapters, the basic building blocks of composition were individuals, truth values and the semantic types that can be constructed out of these entities, as described in the section on type driven interpretation in Chapter 6. In the chapters on propositions and intensions, we added possible worlds, points of time, and contexts of utterance as primitives in our little particle zoo. We now ask the reader to consider **events** as new primitive entities that will turn out useful in dealing with certain aspects of natural language. These entities will, in one way or another, serve as new denotions for certain types of verbs, namely those that describe events or actions.

Event semantics became increasingly popular in the 1990th and it still is today. Nonetheless it did not make its way into textbooks. One of the reasons for this neglect might have been that many formal applications of event semantics in the 1990th dealt with problems of pluralities and plural semantics—a minor topic we briefly touched in passing.[1] However, event semantics as a semantics of verbs was developed independently of these applications; being originally a theory of adverbials and of some lexical aspects of verb meaning, it soon spread to other verb related phenomena like tense and aspect, as well as to areas of verb semantics that deal with perception, causation, change, transition, and other fine-grained aspects of lexical meaning.

Although lexical semantics is not the topic of our book, its results should be compatable with compositional semantics, which calls for an integration of events into the conceptions of sentence semantics. The fact that we still do not find this in textbooks on sentence level semantics will certainly be due to the disturbing fact that event semantics comes in many different flavors, depending on different ways of looking at the basic modes of composition which come along with different Logical Forms quite unfamiliar to those considered to far. Once having introduced the traditional concepts, most textbook authors will hesitate to confront the reader with a plethora of new ideas that all imply certain revisions of beloved practices.

1 See Chapter 5 Section 5.4) and its interactions with the semantics of verbs (cf. Lasersohn (1995), Schein (1994), or Bayer (1997); for parallels between event types and types of nouns, see Bach (1986) or Krifka (1989) and the references cited there.

In this book we will nonetheless try to introduce the basic ideas, focussing on one of the motivating empirical domains, namely the semantics of certain **adverbial modifiers**. Methodologically, we put emphasis on how event semantics determines the mode of composition. We will see that the leading ideas permit for an interesting range of variation and flexibility in composition, alongside with a variety of new semantic types for verbs. Moreover we take the opportunity to introduce concepts like **continuations** and **extended scope** which are important for the semantics of natural language beyond its applications in event semantics.

So what are events and why should they deserve special attention in semantics? Events can be characterized as special entities which, like ordinary individuals, can be located in space and time. They often describe actions and have participants that perform these actions. For example, I (= WS) recently bought a car. This was an action or an "event" that took place on the 24th of July 2019 in Reutlingen, Germany. The same day, a car was sold to me, the same car at the same place at the same time: this follows logically from my buying the car: every buying implies a selling and vice versa. Nonetheless we want to distinguish two different events, with the same things and persons playing different parts in each: e.g., I was the agent of the buying event but not of the selling event. Events, so conceived, are certainly more than just regions in space and time and cannot be characterized by a mere system of coordinates of time, space, and individuals or physical particles.

But beyond that, the question what events really are is a deep one that still occupies linguists and philosopers alike. Clearly, as shown above, events cannot be just physical objects or processes but depend on the way we (as members of a language community) describe and conceive of such purely physical constellations. Seeing the world as just a big heap of atoms and molecules outside the human brain, we wouldn't find any events in it. But as soon as we describe what's going on (buying or selling) we import intentions, causation, perspective, and other intensional stuff. Nonetheless, event semantics manages to get along without possible words, by taking events as primitive entities that are given to us by the way we conceptualize the meaning of verbs.

Instead of speculating on the nature of philosophical entities, we will try to make it plausible that events are indeed useful in the description of certain phenomena having to do with the logic of adverbial modifiers.

1. Adverbial modification

Let us start with some observations that initially motivated the need for events in semantics. Consider:

(1) John slowly crossed the channel by boat

Given that we already have a workable analysis of the truth conditions of *John crossed the channel* we still have to account for the semantics of the adverbial modifiers *slowly* and *by boat*. Since adverbs are closely related to adjectives, it is tempting to derive the meaning of *slowly* from that of *slow*. But here we encounter a difficulty: (1) does not allow the inference that John was slow or acted slowly; he might have been very busy in his actions if he is rowing, but nonetheless the velocity of the boat's movement (not the boat as such) was relatively slow. Likewise, it makes no sense to claim that *by boat* somehow modifies John. Rather we would say that it modifies John's crossing.

This is precisely what is claimed by event semantics: these adverbs, so-called manner adverbs (which can answer the question *How did x do it?*), describe a property of events, namely the event of crossing the channel as performed by John. A somewhat clumsy paraphrase of (1) in the spirit of event semantics is (2):

(2) There was an event of John's crossing of the channel which was performed slowly and with a boat

A crucial trait of this paraphrase is its reference to a certain event that is described by (at least) three pieces of information: it is an event of crossing, it has the property of being quick and the property of being performed with a boat. If such an event exist and was performed by John, the sentence is true, otherwise it is false. The above paraphrase sounds a bit far-fetched, and indeed, nowhere in our earlier semantics of *cross* and *the channel* or elsewhere did we encounter events. Nonetheless it precisely the supposition of event semantics that events are (hidden) components of meaning that come along with the semantics of certain verbs.

Before we can elaborate on the idea, let us make clear that we restrict attention to a certain subclass of verbs and a certain subclass of adverbials. Many adverbs are sentence related and modify propositions, e.g., by specifying judgments of the speaker towards a proposition (*necessarily*, *surprsingly*, *fortunately*, etc.). These are irrelevant to our present concerns. Likewise we

ignore adverbs that specify a property of the subject, as in *Peter arrogantly did not answer the phone call*. Other adverbials also excluded from consideration describe a resultative state. For example, the adverb in *Peter writes illegiably* applies to the result that is produced by writing rather than to the activity itself. See Maienborn and Schäfer (2011) for a brief survey over types of adverbials.

Among the verbs, we exclude from analysis stative verbs like *weigh*, *know* or *resemble* which normally resist modification by manner adverbials.[2]

Having restricted the topic of discussion, our focus is on the logical relations between the sentences in (3):

(3) a. John slowly crossed the channel with a boat
b. John crossed the channel with a boat
c. John slowly crossed the channel
d. John crossed the channel

The reader should verify that (3-d) is entailed by all other sentences, and conversely, (3-a) entails all others. This pattern will be called the **diamond property** of entailment.

EXERCISE 39:

> In mathematical typesetting, the symbol ◊ is called "diamond". Why is the entailment pattern in (3) called "diamond property"? Think of the edges of ◊ as representing entailment!

Now look at the corresponding paraphrases (4) which are intended to reveal the logical structure of the sentences and therefore exhibit the same entailment pattern:

(4) a. There was an event of John's crossing of the channel, this was done with a boat and performed in a slow manner
b. There was an event of John's crossing of the channel, this was done with a boat
c. There was an event of John's crossing of the channel, this was performed in a slow manner

2 We will come back to the difference between stative verbs and the rest in Section 9. The general contention is that stative verbs do not have an event parameter. It should be pointed out that stative verbs can occasionally be reinterpreted (or coerced) as non-stative in the context of a gradual change, as in *Each person will begin to slowly resemble the other.*

d. There was an event of John's crossing of the channel

These logical analyses, also called "Logical Forms" in Davidson (1967), immediately *explain* the pattern we see in (3) because the list of properties of the event is a *conjunction*, and we know that a conjunct like (A and B and C) logically entails (A and B), (A and C), and finally A alone. Moreover the order of conjuncts is random and allows for arbitrary permutations.

We thus have shown that the paraphrases correctly explain the diamond property (see last exercise), as a consequence of reformulating relevant parts of the meaning as a *conjunction* that is not overtly visible in the structure of (3-a). The diamond property was a major motivation for event semantics, whose task is to show how a compositional analysis of (3-a) can generate a Logical Form that corresponds to the paraphrase in (4-a). We have not yet shown, however, that the paraphrases in (4) are superior to possible alternatives without events and without conjunction; we will show this in the next section.

2. Scope and the Failure of Meaning Postulates

Our argument will take the form of a reductio: we will demonstrate that the most reasonable traditional candidate for the semantics of manner adverbials does not work.

Given that adverbials of the relevant kind modify appropriate verbs or verb phrases, it is tempting to construct their meaning as a modifier that maps the meaning of a VPs as already analyzed in previous chapters onto the meaning of the modified VP. This accounts for the recursiveness of the process: we can add an indefinite number of adverbials without restriction. For the sake of simplifying the discussion, assume that intensions do not add anything crucial to the form of the argument, so that the meaning of a VP is simply represented as its denotation, which as we have argued above, is simply a set X of individuals, for example the set of x such that x crosses the cannel in a certain situation s. The most straightforward analysis of adverbial phrases would claim that they restrict X to a subset of X. For example, if John, Paul, and Mary cross the channel, and if *slowly* restricts this set to the set { Paul, Mary }, then only Paul and Mary cross the channel slowly, and (1) would be false. Likewise, if this set is further reduced to Mary by *with a boat*, then only Mary crosses the channel slowly with a boat.

Although this sounds quite reasonable, we encounter a problem when examining the compositional derivation more closely. First we have to establish syntactic structure. Two candidates suggest themselves:

(5) a. John [slowly [crossed the channel] with a boat]

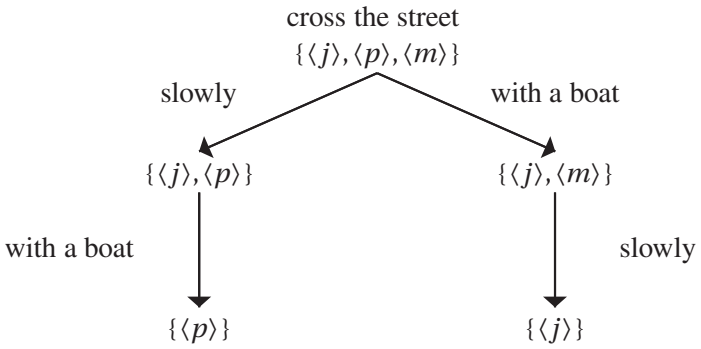
b. John [[slowly crossed the channel] with a boat]

In either case, syntactic structure induces a scope relation that has repercussions for the calculation of the semantic value. We demonstrate this in a small model. Since these considerations do not depend on possible worlds, and since event semantics in general does not refer to intensions, we will omit the index w on the denotation function. Assume now that $[\![\text{cross the channel}]\!] = \{j, p, m\}$, or, more precisely, $\{\langle j\rangle, \langle p\rangle, \langle m\rangle\}$. Moreover, for the sake of the argument, adverbials must be functions from VP-denotations to VP-denotations. These functions are represented as ordered pairs, as shown in (6), the application of the adverbials is shown in (7):

(6) a. $[\![\text{ with a boat }]\!] = \{\langle\{\langle j\rangle, \langle p\rangle, \langle m\rangle\}, \{\langle j\rangle, \langle m\rangle\}\rangle, \ldots,$
$\langle\{\langle j\rangle, \langle p\rangle\}, \{\langle p\rangle\}\rangle, \ldots\}$

b. $[\![\text{ slowly }]\!] = \{\langle\{\langle\{\langle j\rangle, \langle p\rangle, \langle m\rangle, \}, \{\langle j\rangle, \langle p\rangle\}\rangle, \ldots,$
$\langle\{\langle j\rangle, \langle m\rangle\}, \ldots, \{\langle j\rangle\}\rangle\}$

(7)



The reader may verify that (5-a) is true in the model just given (with $[\![\text{John}]\!] = j$ and $j \neq p$) and the analysis in (8), and that (5-b) will be false with the analysis in (9):

(8) $[\![\text{John}]\!] * [\![\text{slowly}]\!] (([\![\text{crossed the channel}]\!])[\![\text{with a boat}]\!])$

(9) $[\![\text{John}]\!] * ([\![\text{slowly}]\!] ([\![\text{crossed the channel}]\!]))[\![\text{with a boat}]\!]$

EXERCISE 40:

Show this in detail!

However, this outcome is not supported by our intuitions about truth conditions: the sentence is not ambiguous and there is no evidence that only one of the syntactic structures should be correct. It follows that syntactic structure should have no impact on the semantic scope relations whatsoever, and that adverbs of this type should not display any scope relations in the first place. But how can we impede adverbs from having scope? Compositionality and the logical type of the adverb simply enforce scope, even if the syntactic structure were flat.

In this sitution one might argue that a proper (conservative) solution should be this: Although a stepwise calculation that technically involves scope is legitimate (for example as in ((A and B) and C) where the second *and* has scope over the first), all one has to do in addition is to restrict the meaning of the adverbs in such a way that the logical properties come out as desired (here: as equivalent to (A and (B and C))). In particular, one might claim that the following condition has always to be met:

(10) for all VPs,
$[\![\text{slowly}]\!] ([\![\text{with a boat}]\!] ([\![\text{VP}]\!])) =$
$[\![\text{with a boat}]\!] ([\![\text{slowly}]\!] ([\![\text{VP}]\!]))$

(10) would rule out the model we stipulated above in (6). In general, it should hold that for the type of verbs and adverbs under consideration, ADV_1 (ADV_2 VP) is logically equivalent to ADV_2 (ADV_1 VP).

EXERCISE 41:

Construct an alternative to (6) that assigns different denotations to *slowly* and *with a boat*, and satisfies the requirement in (10) without satisfying the diamond property.

However, there are problems with this kind of solution: (1) The number of possible adverbials is surely larger than two, we would need a rule for each

pair of manner adverbials. (2) The number of adverbials that may occur in a clause is not limited to just two; we would have to allow for an infinity of meaning rules. (3) Even if we allowed for such permutation schemes, we would still not be able to account for the diamond entailment property. (4) We are still unable to state any reason for the permutability in terms of the intrinsic semantics of an adverb taken in isolation.

Although this makes any solution along the above lines very unattractive, to say the least, one might still try to safe the theory by arguing that permutation schemes are the wrong kind of meaning postulate. A better solution might result from a certain parallelism between adverbs and adjectives. Observe that certain adjectives, also called intersective modifiers, do not exhibit scope properties either:

(11) Arnim is a gray-haired, blue-eyed gentleman in his seventieth

These adjectival expressions also satisfy the diamond property, hence behave logically like the adverbs under discussion. This follows from our earlier rule of composition $[\![\mathrm{A} + \mathrm{N}]\!] = [\![\mathrm{A}]\!] \cap [\![\mathrm{N}]\!]$. But assume now that adjectives are functions from properties to properties. Nonetheless, the diamond property of these modifiers *can* be described by an appropriate meaning postulate.

The point of departure of this analysis is the observation that other adjectives like *fake* or *distinctive* are not intersective, i.e., do not obey to rule (73) of Chapter 5. For example, *fake* could be construed as an adjective that maps a noun phrase meaning X (take the extensional version for simplicity, which is simply a set of individuals) onto another such denotation Y' (a set again, but not a subset of X, namely the set of faked things). Such adjectives do have scopal properties that block permutation. Now, if one wants to maintain that all adjectives have the same logical type, the intersective adjectives, although having the same logical type as all others (namely a function from sets to sets), must in addition satisfy a meaning postulate that restricts Logical Space in a way that satisfies the diamond property and permutability. Such a meaning postulate is (12):

(12) For all intersective permutable adjectives α there is a property α' such that for all noun denotations N, $\alpha(\mathrm{N}) = \mathrm{N} \cap \alpha'$.

(12) claims that α as a function from properties to properties can be "reduced" to a simple property α' that is intersective (thereby satisfies permutation) and allows entailment. This kind of type-reducing meaning postulate is standard

in Montague Grammar. The "real adjective" is α' (denoting a set of individuals) but for the purpose of uniform composition all adjectives (including the non-intersective ones) have undergone a little bit of type shifting to the more complex logical type of α; this shift can be "undone" by the meaning postulate (12).

Now if we think of VP-extensions as playing the same role as nouns, a meaning postulate of the type stated above clearly implies the desired inferential pattern. But it has an undesirable, totally devastating side-effect: Since VP denotations are like Ns in denoting properties of individuals, adverbs must also denote properties of individuals, that is, properties of the subject! But as demonstrated above this is the wrong result.

What the analogy to adjectives reveals is that we get the intended logical behavior only if adverbials apply to simple entities, not to sets. But what kind of entities? Of course events! Or, at any rate, no other plausible candidates that could do the job are in sight. But then, VPs should denote properties of events as well. Of course, such an outcome requires a lot of reanalysis and, indeed, as mentioned above, event semantics comes in a number of different flavors that reflect different methods of translating sentences into logical representations. The main devide is between so-called "Davidsonian" and "Neo-Davidsonian" semantics which will be explained in the next section.

3. "Davidsonian" and "Neo-Davidsonian" Event Semantics

The origin of so-called Davidsonian semantics is his seminal 1967 article "The Logical Form of Action Sentences". In the tradition of analytic philosophy, the term "Logical Form" is used in a sloppy way: the general intention was to reveal properties of ordinary language by using the terminology and notation of formal logic as an analytical tool. In particular, what Davidson proposed were paraphrases with an explicit formalization in mind which provides verbs with an extra event argument. Hence, in the "hidden structure" revealed by logical analysis, every n-place action verb is now represented by an $n+1$ predicate with an additional argument place for an event variable:

> For example, we would normally suppose that "Shem kicked Shaun" consists in two names and a two-place predicate. I suggest, though, that we think of "kicked" as a *three*-place predicate, and that the sentence be given in this form:

(17) $(\exists x)(\text{Kicked}(\text{Shem}, \text{Shaun}, x))$.

> If we try for an English sentence that directly reflects this form, we run into difficulties. "There is an event x such that x is a kicking of Shaun by Shem" is about the best I can do, but we must remember "a kicking" is not a singular term. (Davidson (1967), p. 92)

In later years it became widely accepted to reserve the letter *e* for variables that denote events, and the position of this variables shifted from the end of the relation to its beginning (by convention). Moreover, we have to decide whether the adverb is represented with or without its suffix *-ly*; most authors prefer the adjectival form. Accordingly, *Shem kicked Shaun violently* now became (13):

(13) $(\exists e)(\text{kicked}(e, \text{Shem}, \text{Shaun}) \text{ and } \text{violent}(e))$

As a formula of logic, (1) then turns into (14):

(14) $(\exists e)(\text{crossed}(e, \text{John}, \text{the-channel}) \wedge \text{slow}(e) \wedge (\exists x)(\text{boat}(x) \wedge \text{with}(e, x))$

Predicates like *slow* or *violent* can apply to individuals and to events, and thus take as their extension mixed sets that comprise individuals and events alike. Only as adverbial modifiers they take the grammatical form of an adverb, i.e., the form *slowly* and *violently* respectively, but this change of morphology has no effect on their meaning.

EXERCISE 42:

> In the same manner, formalize (15) and give a paraphrase beginning with "There is an event . . . ":
>
> (15) Jones buttered the toast in the bathroom with a knife at midnight

Davidson devotes a good deal of his discussion to previous attempts of other philophers who proposed alternative Logical Forms or tried to reduce events to other types of entities (see also Parsons (1990), Chaper 8); no attempt was made, however, to show how his "logical forms" can be derived from the surface structure of natural language sentence. This will we our task in the sections to come.

Turning next to so-called **Neo-Davidsonian Event Semantics**, the traditional point of reference is Parson's 1990 book "Events in the Semantics of English". This analysis combines Davidson's treatment of adverbials with

the use of semantic roles like agent or theme as discussed in Chapter 4 Section 5. Almost everything said there about thematic roles is compatible with Neo-Davidsonianism; the crucial difference is that thematic roles, apart from determining the order of arguments in syntax, also appear as semantic entities in the logical analysis of action sentences. Like Davidson's, his analysis is formulated in a logical symbolism as shown in (16-c): :

(16) a. John carefully sliced the salami with a knife
b. There is an event of slicing of which John is the agent, the salami is the theme, and it is done carefully and with a knife
c. $(\exists e)(\exists x)(\text{slicing}(e) \wedge \text{agent}(e, \text{John}) \wedge \text{theme}(e, \text{the-salami}) \wedge \text{careful}(e) \wedge \text{knife}(x) \wedge \text{with}(e, x)$

Unlike before when we took thematic roles as primitives in pairs like $\langle \text{agent}, \text{John} \rangle$, we now take thematic roles as two-place relations between events and individuals, so that the statement that John is the agent of e is re-encoded as $\langle e, \text{John} \rangle \in [\![\text{agent}]\!]$.

Comparing Davidson with Parsons, the crucial obvious difference concerns the arity of verbs: what has been an n-place relation in the traditional analysis and an $n+1$-place relation Davidson's, now reduces to a one-place property (of events) that comes along with n different thematic roles. Moreover, it seems that the Logical Form proposed by Neo-Davidsonians is even more remote from the syntactic surface than Davidson's original proposal. For this reason, we will first present an analysis along the lines of Davidson and then show how the Neo-Davidsonian theory can be extended to the deal with thematic roles.[3]

4. Plugging, Modification, and Existential Closure

There is one element common to Davidson's and Parsons's analysis: both claim the *existence* of a certain event that is described by the contents of the sentence. This logical element, often called **existential closure** and written as $(\exists e)$, quantifies over the event variable and binds it. Crucially, it is not overtly present in the morphemes of the sentence and it is in no way obvious how to import it into Logical Form. There are several options. For the time being, we

3 Davidson himself, in Chapter 11 of his book, makes a rudimentary proposal how to translate natural language into Logical Forms, but his use of "templates" is far from compositional, hence useless for our present concerns.

make a rather simplistic assumption, namely that there is a rule that inserts an existential "for some event"-phrase at the end of the computation. We will modify this assumption later, but let us see how far we can get with it and try a derivation of (17) in a Davidsonian framework:

(17) Brutus | violently | stabbed Caesar |

Ignoring tense for the moment, the verb *stab* denotes a three place relation, i.e., a set of triples $\langle e, x, y\rangle$ such that e is an event, x is the stabber (the agent or subject) and y the thing stabbed (the patiens or object). We now proceed as follows:

1. We plug in *Caesar* at the position of y. This yields a set of pairs $\langle e, x\rangle$ such that e is an event of stabbing Caesar and x is the stabber of this event. This is the VP-denotation of *stabbed Caesar*.

2. Next, we have to combine this result with the adverb which denotes a set of events. For this to work, we provisionally assume a new rule of **adverbial modification**, which preserves the arity of the VP-denotation but reduces the set of pairs $\langle e, x\rangle$ (the VP-denotation) by removing all pairs in which e is not an event that was performed violently. The set of violent e's is the denotation of the adverb.

(18) Adverbial modification:
$[\![\text{Adv + VP)}]\!] = \{\langle e, x\rangle : \langle e, x\rangle \in [\![\text{VP}]\!] \text{ and } e \in [\![\text{Adv}]\!]\}$

Applying this rule, [violently stabbed Caesar] holds of an event e and an x iff x is the subject of a violent stabbing e of Caesar.

3. We plug in *Brutus* at the position of x. This yields the set of events e such that e is a violent stabbing of Caesar performed by Brutus.

4. We finally come back to the assumption that the Logical Form of (17) contains a hidden operator "for some event" which combines with the result of step 3. Intuitively, the result is the truth value true if this set is non-empty, otherwise the sentence is false. More formally we may define an operator "ExClosure" as the combination of an existential quantifier *a(n)* (or *some*) with the noun *event*, which denotes the set of events:

(19) ExClosure := $[\![a(n)]\!] *_L [\![\text{event}]\!]$

We then combine this quantifying expression with the result of step 3 by plugging. The complete calculation is shown in (20):

(20) ExClosure * $\boxed{[\![\text{Brutus}]\!] *_R ([\![\text{violently}]\!] + ([\![\text{stab}]\!] *_R [\![\text{Caesar}]\!]))}$

5. Tense, Negation, and Existential Closure

Although existential closure is unproblematic from the perspective of composition, it creates a problem in sentences like (21), repeated from Chapter 8 Section 7:

(21) Mary didn't turn off the stove

Recall that we distinguished between utterance time, reference time, and event time. Let us denote the utterance time by t_{NOW} and the interval that constitutes the reference time by t_{REF}. We have seen that the past tense supplies the information that the reference time intervall t_{REF} is before t_{NOW}. Otherwise the reference time is pragmatically determined by the context of utterance and the intention of the speaker. Moreover, it is obvious that each event is located in time and space. Let t_e denote event time, i.e., the time interval in which the event e takes place. We can then paraphrase (21) as:

(22) t_{REF} is before t_{NOW} and it is not the case that there is an event e such that t_e is within t_{REF} and e is an event of Mary's turning off the stove.

The information that t_{REF} is before t_{NOW} is presupposed rather than asserted, but this is not really crucial for us here; what makes (22) revealing is the scope of negation which must outscope the existential closure of the event variable. Inserting ExClosure at the end of the calculation does not make any sense: one would assert the existence of an event which is *not* a turning off of the stove, which is trivially true.

This insight can be implemented in various ways. One influential theory claims that existential closure has a fixed place in syntactic structure and comes along with a system called **grammatical aspect**, which was already mentioned in Chapter 8 Section 7. Gramatical aspect is often associated by the progressive tense in English, but since this is a delicate matter, we will ignore grammatical aspect until section 9. Instead, we will concentrate on the consequence of having a syntactically fixed position for existential closure. The syntactic structure is assumed to be the following:

(23) Subject TENSE [PERF [(NEGATION) [ASPECT [VP]]]]

TENSE is either present, past, or future and relates the utterance time t_{NOW} to the reference time interval t_{REF}. PERF is optionally realized by the auxiliary *have* in English, which expresses *perfect tense*, normally called **present perfect** if TENSE is present and **past perfect** if TENSE is past. PERF introduces a new time interval we call **evaluation time**. If *have* is missing, PERF says that the evaluation time interval t_{EVAL} is equal to t_{REF}. If filled by *have*, t_{EVAL} must preceed t_{REF}. NEGATION marks the position of the expression of negation, if present. ASPECT relates the evaluation time to the event time. Until we deal with progressive tense, we assume that the position is phonetically empty. Before defining its semantics, let us illustrate the above with (24), repeated from Chapter 7 Section 7:

(24) John had slept for three hours when Jill came in

The auxiliary *had* splits into *past tense* and *have*. The former says that the reference time interval is before t_{NOW}, *have* says that the evaluation time is before the reference time. ASPECT contains an operator (still to be defined) that locates the event time of John's sleeping within the evaluation time. The adverbial *for three hours* says that the event time fills an interval of three hours, and the *when*-phrase specifies the reference time. It follows that the sleeping occured before the coming which in turn occured before now.

It is generally assumed that (23) also includes a syntactic position AGR for subject-verb-agreement (which hosts person and number features of the verb) and other positions for grammatical categories we can ignore here. A crucial further feature of modern syntactic structures since the 1980th is the hypothesis that the subject is generated within the VP but then moves to the agreement position AGR which is located above tense:

(25) Subj_x AGR [TENSE … ASPECT [(ADVs) [x V Object] (ADVs)] …]

This innovation is extremely relevant for us and has a clear implication for composition: starting off with the verb, we first plug in the object (if there is one) and then the trace x of the subject. The result is a set of events. Then comes any adverb, again a set of events. Composition of verb and adverb is simple intersection. We no more need the special rule (18)!

With this in place, we can now give a preliminary definition of the operator in ASPECT. We call this operator EXCL, because it implies existential quantification of the event variable e.

(26) EXCL = { E : E is a non-empty set of events, and for each $e \in E$, $t_e = t_{EVAL}$}[4]

As an illustration, let VP be *turn off the stove* and x be the trace of the subject. Then the following holds:

(27) EXCL * $x *_R$ [[⟦turn-off⟧ $*_R$ ⟦the-stove⟧]]

iff [[$x *_R$ [[⟦turn-off⟧ $*_R$ ⟦the-stove⟧]]]] ∈ EXCL

iff there is an event e, e is x's turning-off the stove and $t_e = t_{EVAL}$.

We can now add negation, PERF (which says that t_{EVAL}=t_{REF}) and tense:

(28) t_{REF} is before t_{NOW}, and there is no event e, e is x's turning-off the stove and $t_e = t_{REF}$

Last not least, by having moved the subject Mary to the front, this movement generates a property, as described in Chapter 6 Section 4.1:

(29) { x : t_{REF} is before t_{NOW}, and there is no event e, e is x's turning-off the stove and $t_e = t_{REF} = t_{EVAL}$}

And finally we plug in Mary.

To see that the existential closure, as defined in (19), is indeed a part of the definitions of EXCL, the reader should verify that (26) is equivalent to (30):

(30) EXCL = {E : ExClosure($E \cap$ {e : $t_e = t_{EVAL}$})}

This completes our discussion of sentence (21).

EXERCISE 43:

Can you explain the difference in (31)?

(31) a. *Peter has left yesterday
b. Peter left yesterday

4 At this point it seems redundant to have both an evaluation time and an event time. Later, however, we will distinguish between the two, so we decided to keep them apart all along.

EXERCISE 44:

> What is the temporal relation between the two events in the two sentences in (32)? Draw a diagram that locates all time parameters. Show how this follows from the semanic rules laid down above. Assume that both clauses have the same reference time.
>
> (32) Mary arrived at home late. Someone had turned on the stove.

As an interesting consequence of this analysis consider the interaction between EXCL and quantifying NPs. Recall that we could combine a quantified subject directly with a verb or verb phrase that denotes a set of individuals:

(33) ⟦ every cow ⟧ * ⟦ moos ⟧

But now, with ⟦ moos ⟧ denoting a set of events, this combination is impossible. A standard way out is Quantifier Raising across the existential closure:

(34) ⟦ every cow ⟧ * { x : EXCL{ e : e is a mooing of x } }

(34) implies that for each cow there is a mooing event. This seems analogous to *every cow loves a goat*. But not quite: whereas in the goat case the truth of the sentence does not guarantee that for every cow there is a different goat, we normally assume that for every cow there is a different mooing event. This is due to the assumption that verbs denote minimal events: each event is a function that uniquely determines its participants. In other words, if $\langle e, x\rangle$ and $\langle e', x'\rangle$ are in the denotation of *moo*, then $x \neq x'$ implies $e \neq e'$.

6. Neo-Davidsonian Composition

In this section we will briefly look at the Neo-Davidsonian semantics, but only with respect to the mechanism of composition. Recall that in Neo-Davidsonian semantics both verbs and adverbs denotes one-place properties of events; in addition we need thematic roles like "agent" or "theme" that relate the events to its participants. Let us try an analysis of (35):

(35) John sliced the salami with a knife carefully

We can add a little bit of structure for tense, aspect and the movement of the subject across the PAST-morpheme *-ed*, but all this is irrelevant because the only difference between the Davidsonian and the Neo-Davidsonian approach

emerges with the composition of the material inside the innermost box of (36):

(36) John$_x$ PAST EXCL [[x slice the salami] with a knife carefully]

As is clear from the paraphrase in (16) the phrase *the salami* is now the object to a thematic relation, called *theme* above, such that the result is a set of events:

(37) { e : THEME(e, the-salami) }

The rule which combines (37) with the verb is simply intersection:

(38) ⟦ slice ⟧ ∩ { e : THEME(e, the-salami) }

Next we add the subject as the agent, again by intersection:

(39) a. Subject: { e : AGENT(e, x) }
b. { e : AGENT(e, x) } ∩ ⟦ slice ⟧ ∩ { e : THEME(e, the-salami) }

We then go on by adding adverbials; in each step the logical type of the constituents remains the same: the denotation is always a set of events and the semantic operation is intersection throughout, until we end this process by EXCL. Can we therefore dispense with plugging? No, because the thematic roles and the prepositions themselves are two-place relations whose further analysis still requires plugging of their second, non-event argument position. This is not shown in (39) but spelt out in (40):

(40) (⟦ AGENT ⟧ $*_R$ x) ∩ ⟦ slice ⟧ ∩ (⟦ THEME ⟧ $*_R$ ⟦ the salami ⟧)

We have seen in this section that Neo-Davidsonianism does not pose any particular problems for compositionality. But is it also preferable to Davidsonianism? This is a hard question. To see what is at stake we will look at some of the differences between the theories in the next section.

7. Comparisons

For ease of reference we will abbreviate “Davidsonian” with D and “Neo-Davidsonian” with ND.

Let us begin with listing the most obvious differences: ND Logical Forms contain thematic relations and the main mode of composition is conjunction. D Logical Forms use conjunction only for adverbial modification, otherwise the mode of conjunction is plugging; no thematic roles are required. Whereas the arity of the verb is directly encoded in the semantic type of the verb in D-representations, there is only one logical type for verbs in the ND analogue. In the D-theory, argument expressions are added obligatorily in a type-driven way, in order to finally arrive at a truth value. In ND-theories, there is no semantic compulsion to add arguments. Nonetheless, the lack of arguments often causes ungrammaticality:

(41) a. John shocked the children
b. *Shocked the children
c. *John shocked
d. *Shocked

We have already discussed in Chapter 4 Section 5 that such sentences violate rules of Theta Assignment. In Generative Syntax, such sentences are excluded by the so-called **theta criterion**: each verb comes along with a sequence of thematic roles, called the **theta-grid** of the verb, and according to the theta criterion each such thematic role must be assigned to positions in syntactic structure, following the order of the theta roles in the theta grid, and these positions must be filled with appropriate expressions (which excludes certain empty categories as realizations of thematic roles). Accordingly, (41-b-c) constitute a violation of the theta criterion.[5]

By contrast, the thematic relations used in ND theories are not formal features but genuine semantic relations. They specify aspects of the meaning of verbs. Hence they are not the same kind of entity as the elements of the theta-grid. Nonetheless the intuitions about both kinds of entities are often the same. For example, agents can be characterized as being concious, exercising control over the event, and causing the event to happen, etc. (cf. Dowty (1989,

5 See also Jackendoff (1987). It is often assumed that the theta roles determine hierarchies, e.g., "agent > recipient > patient" for dynamic verbs and "experiencer > stimulus" for stative verbs (cf. Primus (1993), p. 701), which are mapped to syntactic positions (also called grammatical functions like subject, direct and indirect object) in the obvious way: an element higher up in the hierarchie must syntactically c-command an element lower in the hierarchie. Theta roles are often decomposed into feature bundles, with subfeatures that express generalizations over sets of theta roles; see e.g. the feature system in Ostler (1980) or Reinhart (2003).

1991)). These are semantic properties of agents, but can also reappear in the formal feature system, e.g., by a feature [+cause] as in Reinhart (2003). In consequence, if the position of thematic relations in a syntactic structure is determined by mapping theory which in turn relies on theta-roles, the ND theory makes a double use of the same notions: one as semantic relations to interpret arguments semantically, the other as parts of the theta-grid that determines obligarory argument positions.

Of course, the formal feature and the semantic relation need not have the same name, but in practice they often do. Nonetheless there is a clear difference which can be illustrated with a similar case of selection. Clearly, the adjective *content* selects the preposition *with*. Hence the lexical entry will contain a feature, say [+with], that enforces a prepositional phrase headed by *with*. But neither the feature [+with] nor the sequence of phonemes should be confused with the two place relation ⟦with⟧. But whereas in the case of content, the preposition *with* does not have any meaningful content, a formal feature like [+agent] always requires a semantic relation ⟦agent⟧.

Having clarified the selection of thematic roles, let us now turn to an argument in favor of the ND architecture of grammar. The argument takes advantage of the uniform semantic type of the verb and the above mentioned fact that there is no semantic compulsion to express semantic arguments. This is exactly what we find with **nominalizations**, i.e., nouns with a verbal root. Let us first consider a simple case like (42):

(42) a. The train arrived slowly
b. The train's arrival was slow

These sentences are logically equivalent, and this is easily captured by giving them exactly the same Logical Form, either D as in (43-a) or ND as in (43-b):

(43) a. $(\exists e)$(arrive(e, the train) and slow(e))
b. $(\exists e)$(arrive(e) and theme(e, the train) and slow(e))

Now consider a more complex example which illustrates that all the arguments of a verb are optional in nominalizations:

(44) a. the destruction
b. the destruction of the city
c. the destruction of the city by the Romans
d. the Roman's destruction of the city
e. the Roman's destruction

. . . happended at midnight

In all theses cases, the noun *destruction* denotes the same object as the verb *destroy* and has identical thematic roles. But these can but need not be realized, just like adjuncts. The verb *happen* takes events as arguments and the determiner *the* has its usual semantics, in fact, all quantifiers retain their usual semantics, as described in Chapter 6:

(45) a destruction/every destruction/most destructions happened at midnight

The relation between verb and noun is even more obvious in nominal gerunds:

(46) Mary's singing broke the glass

Indeed, Parson suggests "that the meaning a of verbal event noun contributes to logical form *exactly the same* predicate of events as the verb from which it is derived." (Parsons (1990) p. 129) The only difference is morpho-syntactic.

A similar argument could been advanced for *by*-phrase in verbal passive constructions; consider (47):

(47) the city was destroyed (by the Romans)

In favor of the ND theory one might argue that it allows us to analyze such by-phrases simply as what they are, namely as optional adjuncts.

Proponents of the ND theory thus argue that their Logical Forms allow for a very simple semantic theory that applies to verbs and nominalized verbs in the way, without further semantic complications.

However, the fact that we can omit arguments without damage for semantic well-formedness does not imply that NDism is an overall simpler theory: as argued above, the freedom to omit has to be compensated by additional syntactic mechanisms like the theta criterion. And even in the case of nominalization, some syntactic requirement must regulate which thematic relations, if realized, can go to which positions. Moreover, the attractiveness of *by*-phrases as adjuncts is diminished by the observation that their theta role is not determined once and for all, as with all other adjuncts, but depends on and must be identical with that of the subject of the active construction. Hemce more must be involved than simple adjunction.

Thus far, then, ND-ism has no clear advantage over a D-theory: whereas the selection of arguments is driven by semantic types in the D-theory, it must rest on additional syntactic mechanisms in the ND-theory. One might

say that at half time the score is a draw; those who find the double use of thematic roles in a ND setting problematic (or the use of thematic roles in general), might score 2:1 in favor of a D implementation. But then we did not ask how the traditional and the D-theory could handle missing arguments that are selected but need not be realized in certain syntactic configurations. Suppose we start off with a lexical entry for *sing* and want to derive the nominal *singing* as in (48):

(48) The singing occured at midnight

In the ND theory, we have a meaning postulate for the lexical entry of *sing*:

(49) For all e, if e is a singing, then e has an agent and e has a theme.

But this does not imply any semantic obligation to realize the thematic roles in syntax. Which is just what we need to analyze (48). In the D-theory the argument positions are already there and come along with the semantics of the verb; in order to derive (48) they should be plugged by existential closure:

(50) $[\![\text{singing}]\!] = \{ e : \text{for some } x \text{ and some } y, \langle e, x, y \rangle \in [\![\text{sing}]\!] \}$

But having done so (perhaps via a lexical rule and in tandem with the affixation of *-ing*) one has no access to the argument slots in constructions like *Mary's singing*. The reason is that existential closure has filled the argument slots once and for all, and there is no way to get a hand on these positions once they are bound by existential closure. Likewise, if a rule of passive would assign to *Rome was destroyed* the meaning of *Rome was stroyed by someone*, we could not optionally add a *by*-phrase (*by the Romans*) because the argument slot of the subject is already "consumed" as a consequence of existential closure. No comparable problem arises in the ND theory.

The Davidsonian must therefore assume that existential closure cannot apply at the level of (modified) lexical entries but can only appear "silently" in syntactic structure; a silent closure operator gets inserted as an argument just in case an overt argument is missing.[6] This seems a bit unwieldy, but what makes this alternative no better than the ND one: the application of this operation cannot be totally optional, otherwise we would be back to the problems posed by (41). As an additional complication, then, the Davidsonian

6 In case this operator is defined simply as $\{X : X \neq \emptyset\}$. It is an existential quantifier that must be interpreted *in situ*, as described in Chapter 6 Section 4.2.

has to stipulate that such empty operators are legitimate only in the domain of nouns and as a *by*-phrase argument in passive constructions.

In sum, then, the game is drawn again, and we need a penalty shoot-out.

Actually, we are not aware of any knock down arguments against either theory, but many linguists prefer ND analyses for reasons of perspicuity and elegance. Nonetheless the question to be decided is also an emprirical one: if ND is to win, there should be phenomena in natural language that cannot be described without the help of thematic relations as necessary elements *in Logical Form*. We have not yet seen any formal proof towards that end (cf. also Bayer (1997), but see the discussion of example (99) below.).

From the above it follows that specific ND thematic relations are irrelevant for any sentence level semantic process and could therefore, on the level of truth conditions, be dispensed with—although at the cost of elegance and perspicuity of the overall theory. As we will see below, thematic relations enable us to state generalizations over arbitrary positions of an argument structure *in semantic terms*—a technical advantage that, at the end of the day, seems to speak in favor of ND.

8. Types of Event Denoting Predicates

Events evolve during time. Different types of developments can be distinguished that determine the semantic well-formedness of many constructions. The best-known classification of verb types that refers to temporal properties of events is due to Zeno Vendler (1957) who distinguished four major classes he calls **activities**, **accomplishments**, **achievements**, and **states**. As a very coarse guideline, we may say that states do not develop in time, activities develop in time without major changes, accomplishments develop and gradually come to an end, and achievements involve a sudden change. Here are some examples, quoted from Vendler op. cit., p. 150.

> There is a very large number of verbs that fall completely, or at least in their dominant use, within one of these categories [footnote omitted]. A little reflection shows that running, walking, swimming, pushing or pulling something, and the like are almost unambiguously cases of activity. Painting a picture, making a chair, building a house, writing or reading a novel, delivering a sermon, giving or attending a class, playing a game of chess, and so forth, as also growing up, recovering from illness, getting ready for something, and so on, are clearly accomplishments. Recognizing, realizing, spotting, and identifying something, losing or finding an

> object, reaching the summit, winning the race, crossing the boarder, starting, stopping, and resuming something, being born, or even dying fall squarely into the class of achievements. Having, possessing, desiring, or wanting something, liking, disliking, loving, hating, ruling or dominating somebody or something, and, of course, knowing and believing things are manifestly states.

Vendler demonstrates the relevance of this classification by a number of tests. The first shows that states are incompatable with the progressive (p. 144).

(51) What are you doing? *I am knowing

Next (p. 145), he separates activities from accomplishments: whereas the former have no set end point, the latter normally have.

> Accordingly, the question "For how long did he push the cart?" is a significant one, while "How long did it take to push the cart?" sounds odd. On the other hand, "How long did it take to draw the circle?" is the appropriate question, and "For how long did he draw the circle?" is somewhat queer. And, of course, the corresponding answer will be, "He was pushing it for half an hour" and "It took him twenty seconds to draw the circle" or "he did it in twenty minutes" and not vice versa. Pushing a cart may go on for some time, but it does not take any definite time; the activity of drawing may also go on for a time, but it takes a certain time to draw a circle.

Quite a number of linguistic tests show the relevance of Vendler's classification, see Section 2.2. in Dowty (1979) for a survey. In this book we will concentrate on the contrast between *for twenty minutes* and *in twenty minutes*. The former selects a state or an activity denoting verb phrase, whereas the latter is compatable with achievements and accomplishments.

In the literature on these verbal classes, also called **lexical aspect**, numerous systems were designed to formally define them in terms of developmental properties of events, ranging from very simple to very complex. We cannot do justice here to any of these classifications, but pick out just one feature that is relevant for verbs that describe activities and states. These are precisely the predicates that satisfy the property of cumulativity:

(52) A predicate P is **cumulative** iff for all x and y, if x has P and y has P, then $x + y$ also has P.

Now what is $x + y$? Suppose x and y are running events. Then $x + y$ is the smallest event z that has x and y as its parts. It is thus assumed that events

have the same structure as the time intervals they determine: both can have parts and may or may not overlap. The predicate *running* is cumulative, because two events of running make for another larger event of running. *for*-adverbials combine with cumulative predicates, whereas *in*-adverbials are incompatable with them.

As Vendler has pointed out, while *running* is an activity predicate, *running a mile* is an achievement. It thus cannot be cumulative: Assume John is running a mile and then continues by running another mile. Summing up the two events make for running two miles, hence cumulativity fails.

This analysis raises a number of questions for our compositional analysis in terms of events. How can we explain that the addition of an argument of the verb can turn an activity into an achievements? Here are two more data that help to define the problem:

(53) a. John drank wine for an hour/*in an hour
b. John drank a gallon of wine in an hour/*for an hour

(54) a. John ate apples for/*in ten minutes
b. John ate an apple in/*for ten minutes

It is obvious that arguments must have some influence on the type of event as a whole. Now observe that *wine* and *apples* are cumululative predicates: if we sum up two portions of wine, the result is a portion of wine again. But if we take a gallon of wine and add another gallon of wine, we do not get a gallon of wine (but two gallons). Likewise, if we have two sets of apples X and Y, the result of $X + Y$ (which is the union of these sets) is a set of apples again. By contrast, if we have an apple x and another apple y, the result $x + y$ is no more an apple but a set of apples. Likewise, take 5 apples X and another set of 5 apples Y, $X + Y$ will be a set of apples that contains more than 5 and up to 10 apples. Hence, *5 apples* is not cumulative. Now consider the general scheme in (55):

(55) $\phi = \{ e : e \text{ is V(erb) and for some } x, x \text{ is N(oun) and THETA}(e, x) \}$

Krifka (1989) has shown that ϕ is cumulative only if both V and N are cumulative.[7] This explains why certain arguments can coerce activities into

7 Krifka even gives a formal proof we cannot reproduce here. Nonetheless one of its premisses he needs is revealing and tells us more about events in general, namely that THETA is always cumulative: For all theta roles THETA it holds that if TH(e, x) and

achievements: It is precisely those arguments whose predicate N is not cumulative that turn the predicate into an achievement.

If this theory is correct, as we believe it is, we can derive two interesting consequences for the analysis of adverbial modifiers. The first is that *for*- and *in*-adverbials do *not* take events as arguments. The second is that quantifying expressions like *an apple* or *five apples* must be interpreted *in situ*, as discussed in Chapter 6 Section 4.2.

To see why this is so, we first observe, following Vendler, that each individual running (considered as an activity) is at the same time the running of a certain distance, e.g., the running of a mile (considered as an achievement). Hence cumulativity is not a property of an event as such but of a predicate. Likewise, a particular portion of wine (described by a cumulative mass predicate) can at the same time be described as a gallon of wine (considered as a non-cumulative predicate). Again cumulativity is a property of N in (55), not of x. This has two consequences.

First, the *in*- an *for*-phrases must have scope. In particular, it is important that the noun that applies to an argument of the verb is within the scope of the adverbial, otherwise we could not explain the observed change of acceptability. This implies that these adverbials cannot be predicated of simple events, unlike manner adverbials of which we took pains to demonstrate that they do not invoke scope. Rather, these adverbials take as an argument the set of events as described by ϕ above and yields a subset of events: they are functions that apply to a set of events Y and yield a subset of Y, namely the set of events X that last ten minutes, as described in (56):

(56) $[\![\text{in/for ten minutes}]\!] = \{ \langle Y, X \rangle : X = Y \cap \{ e : e_t = [\![\text{ten minutes}]\!] \ \} \}$
Condition: X is cumulative for *for* but is not cumulative for *in*.

Second, the Logical Form of sentences containing these adverbials must guarantee that the existential quantifier that accompanies the noun is in the scope of existential closure for events, otherwise we could not generate the set shown in (55). As a consequence we must assume that the quantifier *an apple* when combining with a theta relation is interpreted in situ in the object position of THETA. Recall from Chapter 6 (47) that *love every girl* can be interpreted as (57):

TH(e', y), then TH($e + e'$, $x + y$). Since $x + y$ often denotes plural objects, this property of theta roles establishes an important link between events and plural semantics.

(57) $\{x : \{y : \langle x, y\rangle \in [\![\text{ love }]\!]\} \in [\![\text{ every girl }]\!]\}$

By analogy, *an apple* in the position of a THEME is now interpreted as (58):

(58) $\{e : \{y : \langle e, y\rangle \in \text{THEME}\} \in [\![\text{ an apple }]\!]\}$
= { e: there is an apple y and $\langle e, y\rangle \in$ THEME }

Adding a subject yields a set of events that can now serve as the input to the adverbials in (56). As it turns out, (58) is not cumulative, hence only the *in*-adverbial is well-formed.

9. Progressive Aspect

One of the tests that separate activities form accomplishments exploits a difference that shows up in the entailment patterns of sentences in the progressive:

(59) a. John was drawing a circle
b. John drew a circle

(60) a. John was running a mile
b. John ran a mile

(61) a. John was crossing the street
b. John crossed the street

In none of these examples can we logically infer the b.-sentence from the a.-sentence, simply because something unexpected could have happened before the accomplishment could be completed:

(62) John was crossing the street when a bus crashed into him

In such circumstances, he never reached the other side of the street, he never ran a mile, he never finished the circle, yet the a.-sentences can be true. In contrast, the inferences in the following sentences with activities are valid:

(63) a. John was feeding his dogs when a car crashed into him
b. John fed his dogs

(64) a. John was pushing a cart, when a car crashed into him
b. John pushed a cart

These phenomena were described by Vendler (1957) p. 100 and are known today as the **imperfective paradox**.

Our task is twofold: first we have to describe the semantic difference between achievements and activities, and second we have to spell out the semantics of the progressive in such a way that the pattern of inference and the interaction with the verb classes can be accounted for.

We will neglect the first task, as it belongs to lexical semantics; suffice it to define accomplishments on an intuitive level by their having a natural endpoint, defined by the existence of the circle, the distance travelled, the arrival at the other side of the street. No such endpoint can be found with activities.

It remains to define the semantics of the progressive. This can and has been done independently of event semantics, but as we will see immediately, older approaches can easily be translated into the framework of events.

Unlike Parsons, we take serious the intuition that drawing a cirlce does not imply the existence of a circle, building a house does not imply that there is a house. (Parsons defends the view that there is a partial, unfinished house or circle that could still serve as the referent of *a circle*, *a house* etc.—a view we do not endorse). Nonetheless one can conclude that the circle would be a *possible* outcome of the accomplishment. This suggests that our analysis involves possible worlds again. Recall from above that the time interval at which the progressive is calculated is the evaluation time t_{EVAL}. As a first approximation, Dowty (1979) p. 146 proposes the following truth conditions for an operator PROG, a proposition ϕ, a world w and an interval I that we take to be the evaluation time of our framework:

(65) (24) [PROG ϕ] is true at $\langle I, w\rangle$ iff there is an interval I' such that $I \subset I'$ and I is not the final subinterval of I' and there is a world w' for which ϕ is true at $\langle I', w'\rangle$ and w is exactly like w' at all times preceding and including I.

(The idea of one possible world being exactly like another up to a certain time is of course the crucial notion here. I take it that it is intuitively clear enough to the reader what this ought to mean.)

Although the definition is further refined in Dowty's book, it is precise enough to see that entailment is blocked simply because the possible world w' (which contains a house or a circle) need not be a continuation of the actual world w (which might not contain a house or a circle).

The counterpart in event semantics is that an event e of a world w can develop in different ways in different worlds. The idea of one possible world being exactly like another up to a certain time implies that two events in different worlds may have identical initial segments in the actual world. E.g., the event of drawing a circle is not necessarily an event in the actual world; rather, only an intitial segment whose event time equals the evaluation time is located in the actual world. This requires that the complement of PROG is an intension, hence a function from possible worlds to sets of events. The analogy to (65) can then be formalized as in (66):

(66) [PROG + ψ] is true at $\langle t_{EVAL}, w\rangle$ iff there is an event e in w and an event e' in some w', e is a subevent of e' but not a final subevent, $t_{EVAL} = e_t$, and $e' \in [\![\psi]\!]_{w'}$.

Now, for this to work properly, it is mandatory that the scope of PROG is wider than the scope of *a circle*. Only then can we prevent the inference that the circle exists in the actual world. This is an important additional evidence to our earlier conclusion that an *in situ* interpretation of certain quantifiers is an option that should not be dismissed with.

Let us now return to the interpretation of ASPECT in case of perfective tense which relates the event time to the evaluation time. We assumed above that PERFECTIVE has no audible phonology in English, and we simply equated the event time with the evaluation time. This was actually a simplification because the event time could be contained in the evaluation time (a natural assumption in case the evaluation time equals the reference time, which can properly include the event time). We thus define the silent empty PERFECTIVE operator as in (67).

(67) [PERFECTIVE + ψ] is true at $\langle t_{EVAL}, w\rangle$ iff there is an e, $e_t \subseteq t_{EVAL}$, and $e \in [\![\psi]\!]_w$.

(67) is not entirely unproblematic. Normally it is assumed that ASPECT has exactly two instantiations in English: PROGRESSIVE and PERFECTIVE. But what about verbs that do not express events? Neither definition could apply. Should (67) therefore split into two rules? Many linguists assume that in such cases the relevant verbs which, according to Vendler's classification, express a state, nonetheless have an additional argument, namely a state argument s in place of the event argument e. States and events are subsumed under the label **eventualities**. If so, the e of (67) has to refer to eventualities

rather than to events. By contrast, the e in (66) still has to refer to events, which explains that the progressive is ungrammatical with stative verbs.

EXERCISE 45:

The adoption of states as additional argument for stative verbs (and adjectives) is disputed, see e.g. Katz (1997, 2000) for counter-arguments. Without states, what is left is time intervals I. E.g., the tenseless proposition *John owns a house* will be true at a pair $\langle I, w\rangle$ iff John owns a house during I at w. Assume that the I of stative verbs corresponds to the event time of event verbs. Can you refomulate (67) in such a way that it applies to state verbs? Assume that ϕ is a function from worlds and time intervals to truth values; your solution should start with (68):

(68) [PERFECTIVE + ϕ] is true at $\langle t_{EVAL}, w\rangle$ iff there is ...

As an alternative solution, one might distinguish between event sentences and state sentences, the latter simply lack the ASP projection (cf. Arosio (2004)).

10. Extending the Scope of Existential Quantification

In case the reader has developed some interest in event semantics he might look into the literature and will find that events have been combined with all possible frameworks and semantic theories. But even within the limits of a particular model of grammar it is surprising to see how heterogenious composition is handled by different authors who share the same convictions. To give the reader just a rough impression of what is at stake, we will sketch some of the ideas that lead to different theory designs, without being able here to go into any technical details. The one and only topic we have chosen as an illustration is the proper treatment of existential closure.

10.1. Extending Scope by Continuations

In Section 5 we postulated a fixed position for existential closure, determined by the syntactic make up of a sentence. Some semanticists are skeptical about the impact of syntax on semantics and in particular about the syntactic stipulation of genuinely semantic material. They claim that it is unneccessary to postulate a silent operator for existential closure. Rather, they assume that the existential quantifier in question already comes along with the lexical entry

of the verb. Taking Neo-Davidonism as a point of departure, the claim is that a verb like *stab* has a denotation of the following kind:

(69) $[\![\text{stab}]\!] = \{ X : \text{there is an event e, e is a stabbing, and e} \in X \}$

This semantics has three components: first, that *e* is a stabbing, as before, second, the existential quantification of *e*, and third, a statement that something more is to be said about *e*, this additional information will be plugged in for *X* when combining *stab* with further elements of the sentence. In a sense, then, this third component extends the scope of existential quantification beyond the "normal" meaning of the verb, since anything that is added is a property of the event introduced by the existential quantifier. The relation between this new semantics for *stab* and the old one is quite systematic. Let us assume that **stab′** is the old predicate denoting a set of events, then (69) can equivilantly be restated as (70):

(70) $[\![\text{stab}]\!] = \{ X : X \cap [\![\textbf{stab}']\!] \neq \emptyset \}$

(69) shows that the verb already comes along with existential quantification, and (70) shows that the verb itself is a quantifying expression in the domain of events.

Suppose we want to add a property of events, e.g., *violently*. As things stand, the only method to combine the denotations in a type driven way is by plugging. The result would be a truth value: there is an event *e*, *e* is a stabbing and done violently. This result is correct, but would prevent us from adding further information about the participants of the event, hence this cannot be the end of the story. And there are well-known techniques to avoid this outcome. In this section we will briefly explain the general idea and then apply it to the problem at hand.

Recall from Chapter 9 Section 4 that the meaning of a sentence as a proposition *p* can equivalently described by the effect *p* has on a given context *C* that represents old information. *p* itself could then be reinterpreted as the set of contexts *C* that are compatable with *p*:

(71) $\{C : C \cap p \neq \emptyset\}$

In this kind of scenario we looked back and described a proposition as its effects on a previously given existing context. But we can also reverse the persepective and describe a proposition as a piece of text that can be continued in one way or other. Then *C* is the set of potential *new* information

compatible with what has already been said. Again, this means that a proposition is represented as all possible propositions that are consistent with it. For example, if p is the set of worlds in which it is raining, let us represent a text that starts with p as [It is raining. . . .] or better as [It is raining and . . .] since the full stop is interpreted as conjunction. Now, take another proposition, like *Fido is barking*. Again, this will be represented as the set of propositions compatable with Fido's barking. We now have (72-a) and (72-b), and in order to interpret the text *It is raining. Fido is barking.* we combine (72-a) with (72-b) by replacing the dots in (72-a) by (72-b), which yields (72-c):

(72) a. [It is raining and . . .]
b. [Fido is barking and . . .]
c. [It is raining and Fido is barking and . . .]]

This still leaves space for further continuations.

Tranlating this into our semantic framework, (72) corresponds to (73):

(73) a. $\{C : C \cap [\![\text{ it is raining }]\!] \neq \emptyset\}$
b. $\{C : C \cap [\![\text{ Fido is barking }]\!] \neq \emptyset\}$
c. $\{C : C \cap [\![\text{ it is raining and Fido is barking }]\!] \neq \emptyset\}$

As the reader may verify the semantic operation that leads from (a.) and (b.) to (c.) is simply intersection. This process may go on for ever, but eventually it should come to an end, so that we finally arrive at an ordinary proposition. This can be done by plugging in a tautology:

(74) [It is raining and [Fido is barking and . . .]] * tautology
= [It is raining and [Fido is barking and tautology]]
= [It is raining and Fido is barking]

Now the basic idea is that any semantic category can have this kind of **continuation**. A semantics that is based on this idea is called continuation semantics; cf. Barker (2002).

Combining continuation semantics with event semantics, it is clear that the semantics in (70) can be interpreted as containing existential closure, the ordinary meaning of stab, and a continuation which can be combined with *violently* and its continuation as shown in (75):

(75) a. $[\![\text{stab}]\!] = \{E : (E \cap [\![\textbf{stab}']\!]) \neq \emptyset\}$
b. $[\![\text{violently}]\!] = \{E : (E \cap [\![\textbf{violent}']\!]) \neq \emptyset\}$

c. $[\![\text{stab violently}]\!] = [\![\text{stab}]\!] \cap [\![\text{violently}]\!] =$
$\{E : (E \cap [\![\text{stab}]\!] \cap [\![\text{violent}]\!]) \neq \emptyset\}$

Again, the type of composition amounts to intersection. In the same manner we could now add the object and the subject as arguments of thematic roles that also come along with condinuations, as shown in (76):

(76) a. $[\![\text{THEME}]\!] = \{\langle E, y\rangle : E \cap \{e : \mathbf{theme}'(e, y)\} \neq \emptyset\}$
b. $[\![\text{THEME}]\!] *_R [\![\text{Caesar}]\!] = \{E : E \cap \{e : \mathbf{theme}'(e, \text{Caesar})\} \neq \emptyset\}$

The big intersection of all these components is the set in (77):

(77) { E : there is an e, e is a stabbing, Brutus is the agent of e, Caesar is the theme of e, and $e \in E$ }

This process of adding information about e can be repeated indefinitely. In order to come to an end, that is, to a truth value, we only have to apply an invisible operation, which says that the sentence is true iff its extension is not the empty set (which means that there is at least one possible continuation, so that the previous text cannot be inconsistent, i.e. false). This is the analogue of adding a tautology. Let us call the final operation that turns sets of properties into truth values **finalization**.

A theory along these lines has been proposed in Champollion (2015). Champollion also wants to show that all quantifiers can be interpreted *in situ*. He shows that this can be done in a theory with thematic roles having scope over the verb, but this implies that the main mode of composition is no longer simple intersection. As for negation, we previously assumed that EXCL applies in the scope of negation which requires a truth value as argument. In the present framework, this could be achieved by applying finalization in the scope of negation. Somewhat ironically, finalization is now required exactly at the position where ExClosure applied in the standard theory. So it seems that little has been gained by having the closure operation right with the verb.

10.2. Extending Binding of Pronouns

Let us now take a closer look at one of Davidson's paraphrases:

(78) Jones buttered a toast. He did it slowly.

According to Davidson, the "it" in the second sentence must refer to an event. But how could this be within the Logical Forms elaborated above? The prob-

lem here is again that the existential closure that introduces the event should not only have scope over the first clause but also over the second.

Neither Davidson nor Parsons addressed this question. As we have seen in the last subsection, one way of extending scope could be to interpret the second sentence as follows: we simply ignore the pronoun *it* and the auxiliary *do*. This would gantantee that the content of the second clause reduces to the set of events that are *slow* and performed by the reference of *he*. However, this solution is rather *ad hoc*. Why should we simply ignore one pronoun (*it*) but not the other (*he*)? And what about Davidson's intuition that *it* refers to an event, if it now comes out as having no semantic content at all?

The solution to this problem will rely on a different, much more general mechanism that extends the scope of existential closure and interprets *it* as a bound pronoun. This kind of solution has been developed by analogy to another well-known problem that is independent of events. Consider the sentences in (79):

(79) a. Jones buttered a toast$_i$. It$_i$ was scoarched and black.
b. A man$_i$ entered a room. He$_i$ saw a woman$_j$. She$_j$ ignored him$_i$

Here again the relation between the coindexed phrases is somewhat mysterious. The truth conditions are correctly represented by the structures sketched in (80) which were derived by QR:

(80) a. A toast$_x$ { x : Jones buttered x and x was scoarched and black }
b. A man$_x$ { x : a woman$_y$: { x : x entered a room and x saw y and y ignored x } }

The syntactic structures in (80) imply that we first attach the second clause to the first (by conjunction) and then apply QR in such a way that it gains scope also over the second clause. But as we have seen in Chapter 6 Section 4.3), QR must be restricted so as to prevent overgeneration, and one of the most approved and established restriction says that QR in general must be "clause bound" (cf. May (1985)), and therefore cannot gain scope beyond the clause it originates from. This excludes QR from gaining scope into the second clause, because the operation that transforms (79) into (80) is illegitimate.

The problem has provoked quite a number of responses, among them Discourse Representation Theory (cf. Kamp (1981) or Kamp and Reyle (1993)), File Change Semantics (Heim (2002)), Dynamic Logic (cf. Groenendijk and Stokhof (1991)), Dynamic Montague Grammar (cf. Groenendijk and Stokhof

(1990)), Situation Theory (cf. Lewis (1975), Barwise and Perry (1983)), unrestrained α-reduction (cf. Klein and Sternefeld (2013)), and others. In none of these theories do sentences simply denote truth values; each of them employs an additional device that somehow allows us to extend the scope of the existential quantifier.

Among the many solutions to this problem, perhaps the most elegant theory that enables existential quantifiers to extend their scope beyond their clause is Dynamic Logic, which manages to memorizes the result of interpreting the existential quantification in the first conjunct (which means that we have to chose an individual that satisfies the restriction and the scope of the existential quantifier; this individual is sometimes called a discourse referent or a witness), and then uses this memory when interpreting the second conjunct and the pronouns he_i or she_j as the things that have been stored in previous conjuncts as discourse referents or witnesses. Unfortunately, the most lucid elaboration of this theory, namely Groenendijk and Stokhof (1991), cannot be explained here without the results of the Appendix. Instead, we will make a humble attempt to derive similar effects in a much more limited setting.

Common to all logic based formal theories is a device that permits us to provide for semantic values for sentences with unbound pronouns like *She$_j$ ignored him$_i$*. This device will enable us to assign a truth value to such sentences, provided the pronouns get a semantic value. This is achieved by a function g which assigns a possible denotation to each pronoun. This function is called **value assignment**, **assignment function** or **variable assignment** and is a parameter that is added to the function $[\![\cdot]\!]$, our notation is $[\![\cdot]\!]^g$. Ignoring events for the moment, the truth conditions for *She$_j$ ignored him$_i$* are as shown in (81-b):

(81) a. for any pronoun pro_i, $[\![\text{pro}_i]\!]^g = g(\text{pro}_i)$
b. $[\![\text{she}_j \text{ ignored him}_i]\!]^g = 1$ iff $\langle g(\text{she}_j), g(\text{him}_i \rangle \in [\![\text{ignore}]\!]$

As a further assumption, all pronouns must be indexed by variables, and we define that $g(\text{pro}_x) = x$. It thus follows that $[\![\text{she}_x \text{ ignored him}_y]\!]^g = 1$ iff $\langle g(\text{she}_x), g(\text{him}_y \rangle \in [\![\text{ignore}]\!]$ iff $\langle x, y \rangle \in [\![\text{ignore}]\!]$.

The function g will reappear in the Appendix as a "variable assignment function" which plays a further role in the interpretation of quantifiers, but for now it will suffice to concentrate on the role of g as assigning values to pronouns.

Given that for an isolated sentences like *She igores him* we do not yet know which individuals should be assigned to *she* and *him*, we take into consideration all possibilities, which means that we look at the set of all assignment functions that make *she$_y$ ignores him$_x$* true: This is $\{ g : [\![\text{she}_y \text{ ignores him}_x]\!]^g = 1 \}$. In Section 4 of the Appendix, this set will be called a **global extension**. The global extension has not yet fixed any determined values for the pronouns, this is left open.

The next step is to combine global extension with the idea of a continuation. Consider simple cases like (82).

(82) A man$_x$ comes in. He$_x$ is drunk.

Now assume that the quantifying phrase a man$_x$ can come along with a continuation P, as shown in (83):

(83) A man$_x$ $\{ x : x$ comes in and $x \in P \}$

The idea common to all applications of continuations is that the missing part, namely P, is provided by the text to follow (or is alternatively cancelled by finalization). As suggested above, the missing part (namely *drunk*) comes in as a global extension of a sentence. This is not quite what we see in (83), but it is easy to relate the property P to a global extension of a sentence, as shown in (84):

(84) A man$_x$ $\{ x : x$ comes in and $\{ g : [\![\ldots]\!] \} \neq \emptyset \}$

Now if we replace the dots by *he$_x$ is drunk*, we get:

(85) A man$_x$ $\{ x : x$ comes in and $\{ g : [\![\text{he}_x \text{ is drunk}]\!] \} \neq \emptyset \}$
= A man$_x$ $\{ x : x$ comes in and for some g, $g(\text{he}_x) \in [\![\text{drunk}]\!] \}$
= A man$_x$ $\{ x : x$ comes in and for some g, $x \in [\![\text{drunk}]\!] \}$
= A man$_x$ $\{ x : x$ comes in and $x \in [\![\text{drunk}]\!] \}$

We can now state the semantics for the quantifier *a* in a formal way. Cleary it takes a restriction N as its first argument (plugged in at the left), the scope S as its rightmost argument (plugged in at its right), and the continuation C, a global extension as its remaining argument:

(86) $[\![\text{a}]\!] = \{ \langle N, C, S \rangle : N \cap S \neq \emptyset$ and $C \neq \emptyset \}$.

This is the basic idea in a nutshell. As before, (86) says that the intersection of N with S is not empty, but in addition it requires that the continuation

can be interpreted in such a way that the global extension can also be true, i.e., satisfied for some values of the pronouns occuring in C. Observe that the quantifier must be QRed and coindexed with the pronoun, otherwise we do not get the indended effect. If the continuation should not contain such a pronoun, nothing damaging happens: in case C is a proposition without any pronoun, its global extension is the set of all possible assignments if the sentence is true, otherwise its the empty set.

It is easy to see that the above semantics can also extend the scope of the existential closure embodied in EXCL, as shown in (87-a). The continuation (87-b) crucially contains the same variable e as (87-a); the combination of the two yields (87-c):

(87) a. $\{ C$: EXCL * $\{ e$: Brutus stabbed Ceasar and $C \neq \emptyset \}$
b. $\{ g : [\![\text{it}_e \text{ was done violently}]\!]^g = 1 \}$
c. EXCL * $\{ e$: Brutus stabbed Ceasar and $\{ \text{g} : [\![\text{it}_e \text{ was done violently}]\!]^g = 1 \} \neq \emptyset \}$
= EXCL * $\{ e$: Brutus stabbed Ceasar and e was done violently $\}$

Unfortunately, this is not quite the end of the story. First, since any sentence can be the continuation of any other sentence and may contain pronouns, all of them must have the logical type of global extensions. Second, the process must be recursive, hence all sentences must have the format of sets of continuations. This also requires a mildly different mode of composition, but the details will not give us any insights beyond the intuition that the pronouns can get an intuitively correct interpretation.

10.3. Donkey Anaphora

Before we come to an end of this chapter we would like to take the opportunity to mention a long-standing problem in the philosophy of language. As already observed by Geach (1962), sentences like (88) have a surprising interpretation.

(88) a. If a man_x owns a donkey_y, he_x beats it_y
b. If a man_x lives in Athens he_x does not live in Sparta
c. If a woman_x loves Bert, she_x is crazy

The logical paraphrases given to (88) usually read as follows:

(89) a. For all men x and for all donkeys y: if x owns y, x beats y

b. Every man who lives in Athens does not live in Sparta
c. Any/every man who loves Berta is crazy

How come that the existential quantification in (88) may turn into universal quantification in (89)? And how can we account for the fact that the pronouns *he*, *she*, and *it* are bound by the quantifier in the first clause? Sentences that permit such a switch have been called donkey sentences, the problem is known as **donkey anaphora**.

Let us first demonstrate that simple Quantifier Raising will not work and test this with (89-c) to which we applied QR, as shown in (90):

(90) There is a woman *x* such that if *x* loves Bert, then *x* is crazy

Adopting the truth conditions of material implication as described in the truth table (52) of Chapter 7, the conditional *If x loves Bert, then x is crazy* is true as soon as *x loves Bert* false. But for this to be the case it would suffice to find an entity *x* that does not love Bert; clearly a devastating result.

In the context of this section it will not come as a surprise that the solution relies on the extended scope of the existential quantifier in the antecedent clause. So we have two components: the quantifier with an extension *C* as in (91-a) and the continuation in (91-b):

(91) a. A_x woman *x* loves Bert and *C*
b. she_x is crazy

By the methods described above, this could combine to (91):

(92) A_x woman *x* loves Bert and *x* is crazy

But this is not what we want. Rather we have to interpret a conditional. Now comes the trick: interpreting *if A then B* as material implication we know that it is equivalent to "it is not the case that (A and not B)"; cf. the equivalence of $(S_1 \rightarrow S_2)$ with $\neg(S_1$ and $\neg S_2)$ calculated in (54) of Chapter 7. It follows that the semantics of *if... then...* takes as an argument the negation of (91-b), conjoins this with (91-a), and finally negates the resulting expression. The result is shown in (93):

(93) It is false that [a woman$_x$ loves Bert] and [*x* is not crazy]

We can now extend the scope of *a woman*$_x$ to the second conjunct, which can be paraphrased as (94):

(94) It is false that there is a woman who loves Bert and is not crazy

By logical reasoning the reader should verify that this is equivalent to: Every woman who loves Bert is crazy! This is as desired. We thus have derived the effect that existential quantification turns into universal quantification by elementary logical equivalences and the use of extended scope.

The literature on donkey anaphora is vast. To the best of our knowledge, one of the first to combine a dynamic system of conjunction with the logical equivalence for material implication was Smaby (1979), but the trick works as well for any of the other systems mentioned above (dynamic conjunction, DRT, dynamic logic, continuations etc.). Nonetheless, donkey sentences pose additional problems of their own, cf. e.g. Heim (1990), Kanazawa (1994), or Kadmon (2001).

11. Further applications

Many applications of event semantics went unmentioned, if only because they create further ramifications we cannot discuss here. Nonetheless we would like to sketch two domains that interact with quantification in interesting ways. The first is the semantics of perceptions verbs. Consider:

(95) a. Mary saw John eat an apple
b. Mary saw John count every penny

A standard claim in event semantics is that what Mary saw was the event of John's eating an apple. If correct, this implies that *see* has an event argument of which Mary is the experiencer, and it also has a theme (or a second argument in a D-framework) which is filled by a second event of which John is the agent. Now two events have come into play, each of which must at some point of the semantic calculation be bound by existential closure. We have seen that this *can* be done some way or other, but is not obvious *how* it should be done—a problem we will not discuss here.

In (95-b), the object of Mary's seeing is John's counting every penny. If events are minimal with respect to their participants, we get a reading in which *every penny* has wide scope, so that for every penny there is a separate counting event seen by Mary. But this might not be the intended interpretation. Rather, Mary's perception could be described as a single event which is the result or the sum of all single countings. In order to get this result,

a non-standard semantics for quantifiers has been proposed (we here adopt, but grossly simplify Krifka (1990)) which allows us to derive the following logical analysis :

(96) $(\exists e)(\exists e')$(seeing(e) and experiencer$(e,$ Mary$)$ and theme(e, e') and for all x, x a penny, there is a subevent e'' of e' such that counting(e''), agent$(e',$ John$)$, and theme(e'', x)

Without making an attempt to be precise, the crucial feature of *every* in this analysis is the introduction of subevents e'' that distribute over the elements of *every*'s domain. The question then arises whether big events like e' can be useful in other contexts as well. And in fact it is claimed they are, if only in the realm of plural semantics. As an example, consider (97):

(97) Five workers slaughtered every cow within a day. That was quick.

Although *every* tends to have wide scope (when compared to *all* which prefers narrow scope), (97) has a reading which does not imply that for every cow there are five workers who slaughtered it. Rather, we can paraphrase (97) roughly as:

(98) There was an event e such that e is the smallest event with a set of five workers as an agent and for each cow x, e contains a subevent e' that was a slaughtering of x. e lasted a day. e was quick.

The big advantage of this paraphrase is that we do not have to specify the agent of e' so that it can be left open how many workers participated in each individual slaughtering.[8] As has been pointed out by Schein (1994), the paraphrase in (98) crucially relies on the ND-framework and should therefore count as an advantage over the obligatory D-specification of arguments for each event.[9]

8 Note that if X is a set and the agent of a slaughtering of a cow we are not entitled to infer that each element of X is the agent of a slaughtering of a cow. This is a peculiarity of the lexical semantics of *slaughter*. Such predicates, famously illustrated in *Five boys lifted a piano*, are called **collective**. By contrast, if X is the subject of eating or dying, the inference must be enforced by an appropriate meaning postulate for these verbs.

9 A defender of D-ism could argue that non-distributive (narrow scope) *every cow* has the same semantics as *the cows* or *all cows*, which yields the representation slaughter(e, X, Y), with X a set of five workers and Y the set of cows. It would then be the task of a meaning postulate to specify that for every $y \in Y$ there is an event e' and a non-empty subset X' of X such that slaughter(e', X', y). It seems that this could rescue the theory for this particular example, but further problems lurk with sentences like (99).

EXERCISE 46:

Compare (97) with (99):

(99) 5 children eat 3 pizzas within an hour. That was slow.

What are the parallels, what the differences?