CHAPTER EIGHT EVENTS: NEO-DAVIDSONIAN EVENT SEMANTICS

"Strange goings on! Jones did it slowly, deliberately, in the bathroom, with a knife, at midnight. What he did was butter a piece of toast."
Donald Davidson 1967, *The logical form of action sentences.*

8.1. The Davidsonian theory [Adapted from Landman 2000]

In this lecture, I will introduce the (neo)-Davidsonian theory of event arguments, and discuss several of the arguments that Terry Parsons gives in Parsons 1990 in favor of this theory. I will discuss some details of Parsons' own proposal in the next lecture. There too, I will present a particular version of the neo-Davidsonian theory, that I will build on in later lectures on plurality.
The Davidsonian theory is a cluster of theories of relations, their arguments and their modifiers. Look at the sentences in (1):

(1) a. Jones buttered the toast.
b. Jones buttered the toast slowly in the bathroom with a knife.

Ignoring verb phrase modification, the classical theory of relations and arguments (as found in e.g. Montague 1973, Thomason and Stalnaker 1973) tells us that the verb butter in sentence (1a) expresses a two-place relation between the two nominal arguments, and that the adverbials in (1 b) are verb modifiers: functions from verbs to verbs; in other words, the verb and the modifiers in (I b) form a complex two-place relation (as in 2b):

(2) a. BUTTER(j,σ(TOAST))
b. ([WITH(KNIFE)(IN(σ(BATHROOM))(SLOWLY(BUTTER)))]) (j,σ(TOAST))

Davidson 1967 proposes that the verb in an action-sentence (i.e., a non-stative verb), like (la), expresses a three-place relation between the nominal arguments and an implicit event argument, which is existentially quantified over; and he proposes that the modifiers in (lb) are added conjunctively as predicates of the event argument. This leads to representations like (3a) and (3b):

(3) a. ∃e[BUTTER(e,j,σ(TOAST))]
b.∃e[BUTTER(e,j,σ(TOAST) ∧ SLOWLY(e) ∧ IN(e,σ(BATHROOM) ∧ KNIFE(WITH(e))]

What is called the neo-Davidsonian theory, which is explored in, among others, Higginbotham 1983 and Parsons 1990, radicalizes this idea by assuming that all verbs, non-statives and statives alike, have such an implicit argument - verbs are not relations, but one-place predicates of events (or states); and it assumes that both modifiers and arguments are added conjunctively, the latter through thematic roles. This gives representations like (4a) and (4b):

(4) a. $\exists$e[BUTTER(e) $\wedge$ AGENT(e)=j $\wedge$ THEME(e)=σ(TOAST)]
b. $\exists$e[BUTTER(e) $\wedge$ AGENT(e)=j $\wedge$ THEME(e)=σ(TOAST) $\wedge$ SLOWLY(e) $\wedge$ LOCATION(e)=σ(BATHROOM) $\wedge$ KNIFE(INSTRUMENT(e))]

We see three salient features that the Davidsonian and neo-Davidsonian theory share:

1. Besides the arguments that are explicit in the sentence, verbs have an extra, implicit argument: an event (or state) argument.
2. Modifiers modify this event argument.
3. In the sentence, this event argument is existentially quantified over.

In Parsons 1990, three kinds of arguments are presented in favor of the (neo)Davidsonian theory: the modifier argument, the argument from explicit event reference, and the argument from perception reports.

I discuss the modifier argument here.

8.2. The modifier argument

I will present Parsons' modifier argument by looking at adjectives first. Look at sentence (5a):

(5) a. John is a blue-eyed, blond, forty year old American with a beard, in his midlife crisis, dressed in a suit.

Kamp 1975 presents and discusses the classical semantic theory of prenominal adjectives. This theory assumes that such adjectives are nominal modifiers, semantically, functions that take a noun (type <e,t>) and turn it into a complex noun (also type <e,t>). This means that semantically, (5a) is analyzed as (5b):

(5) b. DRESSED IN A SUIT(IN HIS MIDLIFE CRISIS (WITH A BEARD (BLUE-EYED(BLOND(FORTY YEAR OLD (AMERICAN))))))(j)

where each of the modifiers has type <<e,t>,<e,t>>(or rather the corresponding intensional type).

There are two problems with the classical analysis:

1. Permutation: Disregarding syntactic distribution constraints (concerning which modifiers are prenominal and postnominal), it seems to be the case that permuting the modifiers in (5a) does not change the truth value of (5a), i.e. (5a) is equivalent to (5c):

(5) c. John is a forty year old, blond, blue-eyed American, dressed in a suit, with a beard, in his midlife crisis.

2. Drop: We can drop any number of adjectival modifiers anywhere in (5a), and (5a) entails the resulting sentence, i.e. (5a) entails (5d):

(5) d. John is a blue-eyed, forty year old American, in his midlife crisis.

There are two kinds of exceptions to these observations, one real and one not real.
In the first place, intensional adjectives like former and potential do not obey Permutation and Drop, as can be seen by the fact that (6a) and (6b) are not equivalent, and that (6c) does not entail (6d):

(6) a. John is a former world-class ballet dancer.
b. John is a world-class former ballet dancer.
c. This is a potential problem.
d. This is a problem.

Such intensional adjectives only occur as prenominal adjectives, not as predicative adjectives, and I will assume that they form a special class that I will not be concerned with here.

The second kind of exceptions are scalar adjectives.
It would seem at first sight that Permutation and Drop do not hold for the large class of scalar adjectives either, cf. (7a)-(7c):

(7) a. Jumbo is a small pink elephant.
b. Jumbo is a pink small elephant.
c. Jumbo is a small elephant.

It is not clear that (7a) and (7b) have the same truth conditions, and if pink elephants are extraordinarily large, (7a) does not intuitively entail (7c).

However, Kamp 1975 argues that scalar adjectives require for their interpretation an implicit comparison class, and he argues that the nature of this comparison class is determined in discourse. Typically, out of the blue this comparison class is determined by the noun that the scalar adjective applies to (i.e. pink elephant in (7a), but elephant in (7b)) but, as Kamp and Partee 1994 neatly show, this is not always the case, cf. (8):

(8) a. My three-year-old built a really huge snowman.
b. The college team built a really huge snowman.

Out ofthe blue, huge in (8a) means: huge in comparison to snowmen built by threeyear-olds. With appropriate stress on snowman, it can even mean: huge in comparison to things typically built by three-year-olds, in which case the noun snowman doesn't play any role at all in the comparison class.

Given this, it is no longer clear that scalar adjectives don't obey the principles of Permutation and Drop. The reason is that the principles of Permutation and Drop obviously have nothing to say about inferences where in the premise and the conclusion the adjectives do not have the same interpretation. Since Kamp analyzes scalar adjectives as predicates, he assumes that principles like Permutation and Drop constrain these adjectives as much as they do other adjectives, and that the putative counterexamples in (7) aren't counterexamples: on the problematic interpretation (which is their natural interpretation), they do not challenge Permutation and Drop, because the comparison class is not kept the same.

The claim that Permutation and Drop hold for scalar adjectives is the claim that (9a) and (9b) are equivalent, and that (9a) entails (9c), assuming that the comparison classes are as given, and this claim seems unproblematic.

(9) a. Jumbo is a small[for a pink elephant] pink elephant.
b. Jumbo is a pink small[for a pink elephant] elephant.
c. Jumbo is a small[for a pink elephant] elephant.

We can assume, then, that, except for the intensional adjectives, the principles of Permutation and Drop hold generally for prenominal adjectives.
The problem then is to account for this.

Theoretically, we have the following problem. We have the following structure:

(10) a. **(A(B(C(N))))**(x)

(l0a) entails any permutation of the modifiers in (l0b):

(10) b. 1. **(A(C(B(N))))**(x)
2. **(B(A(C(N))))**(x)
3. **(B(C(A(N))))**(x)
4. **(C(A(B(N))))**(x)
5. **(C(B(A(N))))**(x)

And (l0a) entails any case with adjectives dropped in (10c), plus their permutations:

(10) c. 1. **(B(C(N)))**(x) 2. **(C(B(N)))**(x)
3. **(A(C(N)))**(x) 4. **(C(A(N)))**(x)
5. **(A(B(N)))**(x) 6. **(B(A(N))(**x)
7. **(A(N))**(x)
8. **(B(N))**(x)
9. **(C(N))**(x)
10. **N**(x)

The standard way to try to ensure this is by means of meaning postulates. One principle that will give us some of these entailments is the so-called meaning postulate of subsectivity:

Subsectivity
For any (relevant) modifier A and simple or complex noun N: **(A(N))**(x) entails **N**(x)
Now (7a) entails (7d), and (7d) entails (7e), and hence (7a) entails (7e):

(7) a. Jumbo is a small pink elephant.
d. Jumbo is a pink elephant.
e. Jumbo is an elephant.

However, such a meaning postulate is not enough, because it cannot give us the entailment from (5e) to (5t):

(5) e. John is a blond, forty year old American.

f. John is a forty year old, blond American.

Nor can it allow us to drop an adjective in the middle, i.e. give the entailment from (5g) to (5h):

(5) g. John is a blond, blue eyed, forty year old American.
h. John is a blond, forty year old American.

To get the latter, we would have to add a principle of monotonicity:

Monotonicity
If **(A(N))**(x) and N entails M then **(A(M))**(x)

So let N be the complex noun in (5i), M be the complex noun in (5j), and let A be blond. Since (Si) entails (5j), it follows with monotonicity that (5k) entails (51):

(5) i. Blue-eyed forty year old American
j. Forty year old American
k. Blond blue-eyed forty year old American
1. Blond forty year old American

However, it seems that to get the full permutation facts, a meaning postulate constraining the meaning of a single modifier cannot suffice. More precisely, what is not sufficient is a meaning postulate that constrains the meaning of a single modifier and does not define the meaning of the modifier in terms of a different lexical item, like the meaning of the corresponding predicative adjective. Rather we would need a postulate on different adjectives simultaneously:

Meaning Postulate: (A(B(N)))(x) iff **(B(A(N)))**(x)

and in fact, because the number of adjectives is unconstrained, we would have to have a general principle like:

Permutation closed
Let PERM(A_1(A_2(... (A_n(N) ...)) be the set of all permutations of the modifiers:

for all Z ∈ PERM(A_1(A_2(...(A_n(N) ...)): Z iff A_1(A_2(... (A_n(N) ...)

The problem is that this is not a meaning postulate on lexical items, but really a postulate on syntactic structure, and on unbounded syntactic structure for that matter. Such a meaning postulate is very unconventional and ad hoc.
Now, this is in fact not what the classical theory assumes for such adjectives. Rather it assume that the relevant adjectives are intersective:

Intersectivity:
For every adjective A in the relevant class and every simple or complex noun N:
(A(N))(x) iff (A_p ∩ N)(x)
where A_p is the corresponding predicative adjective (of type <e,t>).

A more perspicuous way of expressing the same is the following. We know that a modifier takes a noun and forms a (complex) noun. If it does this in an intersective way, its meaning should be represented as follows:

$A := \lambda P \lambda x.P(x) \wedge A_p(x)$

Thus, the prenominal adjective blond takes the predicate American and gives the conjunctive predicate:

(5) m. Blond American
n. $\lambda x.\text{AMERICAN}(x) \wedge \text{BLOND}_p(x)$,

This denotes the property that you have if you are American and blond. After that, Blue-eyed takes this complex predicate and yields the predicate:

(5) o. Blue-eyed blond American
p. $\lambda x.\text{AMERICAN}(x) \wedge \text{BLOND}(x) \wedge \text{BLUE-EYED}(x)$

In this way, a modifier structure (11a) gets interpretation (11b), and filling in the subject withj gives (11c):

(11) a. A(B(C(N))
b. $\lambda x.N(x) \wedge C(x) \wedge B(x) \wedge A(x)$
c. $N(j) \wedge C(j) \wedge B(j) \wedge A(j)$

Since this is a conjunction, it entails any pennutation of the conjuncts and, when you drop any number of conjuncts, the result is entailed. Hence, intersectivity entails both the principles of Permutation and Drop.
What is crucial for this analysis is the following.

We have an modifier modifying a predicate, a noun:

l. The modifier of the noun is conjoined with the noun.
2. Hence, because the noun is a predicate, the modifier of the noun is also a predicate (because you can only conjoin like things).
3. The modifier of the noun is a predicate of the argument that the noun itself is a predicate of.

This is a very persuasive analysis of these adjectives, and it is particularly persuasive, because, as we have seen, there isn't an alternative: if we want to explain these facts without relying on conjoined predicates, we are forced into meaning postulates constraining an unbounded number of adjectives at the same time.

Now let's tum to adverbial modification.
The situation with adverbial modification is, apart from one highly important difference, the same as that of adjectival modification: for a large class of adverbial modifiers, we find the same entailments as with the adjectives.
Here too we will set intensional adverbials like possibly and allegedly, and in general sentential modifiers, aside, and only concentrate on VP-modifiers.

If again we disregard syntactic restrictions on where certain types of adverbials can occur, we fmd Permutation and Drop entailments. Look at (12):

(12) a. Brutus stabbed Caesar quickly in the back through his toga with a knife.
b. Brutus stabbed Caesar quickly with a knife through his toga in the back.
c. Brutus stabbed Caesar in the back with a knife.

For manner adverbials, like quickly, we will assume that they are context dependent in the way scalar adjectives are, and here too, we are assuming that Permutation and Drop only concern inferences where between premise and conclusion we do not chance the interpretation.
Given this, it is indeed the case that (12a) and (l2b) are equivalent, and that they entail (12c).

We can make exactly the same argument as before with adjectives; in fact, the case against alternatives is even worse. Some of the entailments for adjectives could be achieved through a monotonicity condition. However, for adverbials, such a condition is out of the question, because such a principle is not valid. Compare (13) with (14):

(13) a. Every yankee is an American.
b. John is a forty year old yankee.
c. Hence John is a forty year old American.

(14) a. If you talk to a crowd, you move your thorax.
b. John talks to the crowd through a megaphone.
c. Hence, John moves his thorax through a megaphone.

This is a difference with adjectives that will have to be accounted for.
We see a related difference with adjectives if we look at entailment patterns in the opposite direction:

(A(P))(x) and **(B(P))**(x) entail **(A(B(P)))**(x)

This principle is valid for adjectives, as shown in (15), but not for adverbials, as shown in (16):

(15) a. John is a blond American and John is a blue-eyed American.
b. Hence, John is a blond blue-eyed American.
(16) a. Brutus stabs Caesar with a knife and Brutus stabs Caesar in the back.
b. Hence, Brutus stabs Caesar with a knife in the back.

While these differences need to be accounted for, it is the similarity between adjectives and adverbials that is Parsons' strongest argument in favor of the Davidsonian theory. Given that adjectives and adverbials seem to behave so much in the same way, we would want to assume basically the same analysis of both.

This then suggests the following:

l. Adverbial modifiers are conjoined with the predicate they modify.
2. Hence adverbial modifiers are themselves predicates.
3. Adverbial modifiers are predicates of the same argument as the predicate they modify.

The problem is: which argument is that?
One could try to argue that adverbial modifiers are VP-modifiers, and, since VPs are predicates of the subject, so are adverbial modifiers. The problem is that this cannot be correct. If that were the case, then we predict that there is no semantic difference between adverbials and adjectives at all. That is, we predict that adverbials satisfy monotonicity, and hence (14) should be valid; similarly, we predict that they satisty the upward conjunction pattern, and (16) should be valid. But, of course, (14) and (16) are not valid.

The two VPs in (14a) would be analyzed as in (17a) and (l7b):

(17) a. Talk to a crowd through a megaphone:
$\lambda x.\text{TALK-TO}(x,c) \wedge \exists x[\text{MEGAPHONE}(x) \wedge \text{THROUGH}(x)]$
b. Move your thorax:
$\lambda x.\text{MOVE}(x,\text{THORAX}(x))$

Since, intuitively, (17a) entails (17b), (14) would be interpreted as the valid inference in (18):

(18) a. $\forall x[\text{TALK-TO}(x,c) \rightarrow \text{MOVE}(x,\text{THORAX}(x))$
b. $\text{TALK-TO}(j,c) \wedge \exists x[\text{MEGAPHONE}(x) \wedge \text{THROUGH}(j)]$
c. $\text{MOVE}(j,\text{THORAX}(j)) \wedge \exists x[\text{MEGAPHONE}(x) \wedge \text{THROUGH}(j)]$

Similarly, the inference in (16) would be interpreted as the inference in (19):

(19) a. $(\text{STAB}(b,c) \wedge \text{KNIFE}(\text{WITH}(b)) \wedge (\text{STAB}(b,c) \wedge \text{IN}(b,\sigma(\lambda x.\text{BACK}(x,b))$
b. $\text{STAB}(b,c) \wedge \text{KNIFE}(\text{WITH}(b)) \wedge \text{IN}(b,\sigma(\lambda x.\text{BACK}(x,b))$

There is some inherent absurdity here of Brutus being in the back. This is a problem that we might try to deal with through meaning postulates (i.e. we don't have to assume that the fact that the formal relation IN holds between Brutus and the back, entails that Brutus be in the back: we can assume that the meaning postulates on IN do not require this).
More seriously, on this analysis, (19a) entails (19b). which, as Parsons argues, is incorrect, since, Brutus may have stabbed Caesar in the front with a knife, but in the back with an ice pick.
Maybe there are some cases where an adverbial can plausibly be regarded as a property of the subject, or of one of the other explicit arguments in the sentence. Maybe sometimes we do want to infer from John sang grotesquely that John was grotesque, though even there it seems that we cannot reduce this simply to a predication of the subject. In general, such a reduction is out of the question. Look at (20):

(20) Yoshi tapped Susumo lightly on the shoulder.

What is lightly a predicate of? Not of Yoshi and Susumo, who are Sumo wrestlers and far from light. Not of Susumo's shoulder either, which is a good fleshy shoulder.
If we want to capture the similarities with the adjectives - and we do - it seems that we are forced to assume that there is another, implicit argument that the predicate being modified is predicated of, and the modifying adverbial is predicated of this argument.

This is the Davidsonian argument.

The verb stab in (21a) is only superficially a two-place relation(as in 21b); semantically it is a three-place relation as in (21c), or in the neo-Davidsonian version, (21d):

(21) a. Stab
b. $\lambda y \lambda x.\mathrm{STAB}(x,y)$
c. $\lambda y \lambda x \lambda e.\mathrm{STAB}(e,x,y)$
d. $\lambda y \lambda x \lambda e.\mathrm{STAB}(e) \wedge \mathrm{AGENT}(e)=x \wedge \mathrm{THEME}(e)=y$

Given this, we can follow for adverbials the same line of argument as we gave for adjectives. We can treat adverbials as verb-modifiers (or as VP-modifiers, the difference doesn't matter here). As verb-modifiers, semantically they take a verb and produce a complex verb: this complex verb is the conjunction of the original verb and the modifier, predicated of the Davidsonian argument. This gives adverbials the following semantics (as modifiers of transitive verb):

(22) a. *Quickly* →: $\lambda V \lambda y \lambda x \lambda e.V(e,x,y) \wedge \mathrm{QUICK}(e)$
b. *With a knife* → $\lambda V \lambda y \lambda x \lambda e.V(e,x,y) \wedge \mathrm{KNIFE}(\mathrm{WITH}(e))$

In this way the modifier structure (23a) becomes (23b):

(23) a. KNIFE(WITH(e))(QUICKLY(STAB))
b. $\lambda y \lambda x \lambda e.\mathrm{STAB}(e,x,y) \wedge \mathrm{QUICK}(e) \wedge \mathrm{KNIFE}(\mathrm{WITH}(e))$

Filling in the object Caesar and the subject Brutus gives us (24), the event type of quick stabbings of Caesar by Brutus with a knife, or the set of events which are stabbings of Caesar by Brutus and which are quick and with a knife:

(24) $\lambda e.\mathrm{STAB}(e,b,c) \wedge \mathrm{QUICK}(e) \wedge \mathrm{KNIFE}(\mathrm{WITH}(e))$

We're not finished here, since we still have to account for the differences with adjectives. What we observe is this. We find the so-called diamond entailments in (25): (25a) entails (25b), (25b) entails (25c), But (25b) does not entail (25a):

(25)

$$\begin{tikzcd}
 & \text{a. } \mathbf{(A(B(STAB)))}(b,c) \arrow[dl] \arrow[dr] & \\
\text{b. } \mathbf{(A(STAB)))}(b,c) \arrow[dr] & \text{and} & \mathbf{(B(STAB)))}(b,c) \arrow[dl] \\
 & \text{c. } \mathbf{STAB}(b,c) &
\end{tikzcd}$$

We have seen that in the case of adjectives, we find the same downward diamond entailments: (26a) entails (26b) and (26b) entails (26c). But in this case, the entailment from (26b) to (26a) is also valid:

(26) a. **(A(B(AMERICAN)))**(j)

b. **(A(AMERICAN))**(j) and **(B(AMERICAN))**(j)

c. **AMERICAN**(j)

However, the pattern that we see for adverbials is precisely the pattern that we see for adjectives in (27):

(27) a. someone is a blond, blue-eyed American

b. someone is a blond American and someone is a blue-eyed American

c. someone is an American

(27a) entails (27b) and (27b) entails (27c), but this time (27b) does not entail (27a). The intuition is - in the Davidsonian theory - that verbs have an extra event argument and that in some sense (25a) is about an event. There are two verbs in (25b), and the idea is that there are two independent event variables; hence in the sense in which (25a) is about an event, (25b) is about two events. This is the reason why (25b) does not entail (25a). This is achieved if we assume that the event arguments introduced by the verbs are existentially quantified over before conjunction.

Then it will follow that you can drop adverbials as long as they are predicates on the same existential quantifier; but if there are two existential quantifiers, you cannot merge them into one. Thus, the Davidsonian theory assumes that at the sentence level (or discourse level), where the sentence gets its truth value, the truth conditions for the event type involve existential quantification over the event variable.

The diamond results then follow from the Davidsonian representations in (28):

(28) a. $\exists e[\text{STAB}(e,b,c) \wedge \text{KNIFE}(\text{WITH}(e)) \wedge \text{IN}(e,\sigma(\lambda x.\text{BACK}(x,c)))]$

b. $\exists e[\text{STAB}(e,b,c) \wedge \text{KNIFE}(\text{WITH}(e))]$ $\wedge$ $\exists e[\text{STAB}(e,b,c) \wedge \text{IN}(e,\sigma(\lambda x.\text{BACK}(x,c)))]$

c. $\exists e[\text{STAB}(e,b,c)]$

Since there is no guarantee that the events in (28b) are the same event, there is no entailment from (28b) to (28a).

We see the same phenomenon even more clearly in Parsons' examples of adverbial swapping. (29a) and (29b) together do not entail (29c) or (29d): adverbials can not swap from one verb (or occurrence of a verb) to another:

(29) a. Brutus stabbed Caesar in the front with a knife.
b. Brutus stabbed Caesar in the back with an ice pick.
c. Brutus stabbed Caesar in the front with an ice pick.
d. Brutus stabbed Caesar in the back with a knife.

Secondly, monotonicity is not a property of these adverbials either. Let's look once more at (14):

(14) a. If you talk to a crowd you move your thorax.
b. John talks to the crowd through a megaphone.
c. Hence, John moves his thorax through a megaphone.

The semantic representations of the examples in (14) in the Davidsonian theory would be like those in (30):

(30) a. $\forall e \forall x[\ \text{TALK-TO}(e,x,c) \rightarrow \exists e'[\ \text{MOVE}(e',x,\text{THORAX}(x)) \wedge \text{INVOLVE}(e,e')]]$
b. $\exists e[\ \text{TALK-TO}(e,j,c) \wedge \exists x[\text{MEGAPHONE}(x) \wedge \text{THROUGH}(e,x)]]$
c. $\exists e'[\text{MOVE}(e',j,\text{THORAX}(j)) \wedge \exists x[\text{MEGATHONE}(x) \wedge \text{THROUGH}(e',x)]]$

(30a) and (30b) do not entail (30c). Crucially, antecedent and consequent of the conditional in (30a) involve different events. (30b) instantiates the antecedent with an event which is through a megaphone. This does entail that there is a consequent event involved with that antecedent event, but crucially not that this consequent-event is itself through a megaphone.

This, then, is the argument from modifiers. The strength of the argument comes from the analogy with adjectives. If we accept the argument in the case of the adjectives - i.e. if we accept that adjectives are predicates conjoined with the predicate they modify and predicated of the same argument -, it seems that the parallels force us to assume the same for adverbial modifiers, which argues strongly that verbs do have an implicit argument of which both the verb and the modifiers are predicated: an event argument. The strength of a theory is of course directly related to the strength of the available

8.3. Neo-Davidsonean semantics

TYPE: 1. e, η, i, s, t $\in$ TYPE
2. if a, b $\in$ TYPE then $<a,b> \in$ TYPE

e, t, s are as usual the type of individuals, truth values and possible worlds
η is the type of events, i is the type of periods of time (intervals).

Models for the language: $M = <D, E, I, W, \{0,1\}, \tau, \perp, F>$
D: set of individuals
E: set of events
I: set of periods of time (ordered at least by temporal precedence < and temporal inclusion $\subseteq$)
W: set of worlds
$\perp$: the undedefined object, which is not in any semantic domain.
τ is the temporal trace function (see below)

We will not deal properly with undefinedness here (since life is short).
We already allowed undefinedness in $\sigma(P)$ without being very explicit about how this affects truth conditions of complex formulas. We will allow more undefinedness now in the following way.

In a Davidsonian event theory, we will associate with verbs predicates of events of type $<\eta,t>$

hug	$HUG_{<\eta,t>}$	the set of hugging events
purr	$PURR_{<\eta,t>}$	the set of purring events

We call the type $<\eta,t>$ the type of **event types**, so event types are sets of events.
Hence we associate lexically with verbs event types.

In a Neo- Davidsonian theory we associate with argument places of the verbs **thematic roles**, like **agent** and **theme**.

We assume a set of **thematic roles** containing the roles of agent (Ag) and theme (Th), and we assume that thematic roles are partial functions from events to individuals:

ROLE $\subseteq$ $CON_{<\eta,e>}$
Ag, Th $\in$ **ROLE**
If $R \in$ **ROLE** the $F(R) \in (E \rightarrow D \cup \{\perp\})$

Thematic roles specify the participants of events.
Lexical constraints will constrain which roles are defined for which events:

Example:

lexical constraint on *hug*
For every $e \in E$: if $e \in F(HUG)$ then $F(Ag)(e) \neq \perp$ and $F(Th)(e) \neq \perp$

Every hugging event has an agent (the hugger) and a theme (the huggee).

We assume roles as partial functions from events to individuals. But this generalizes, in particular, we assign time and location to events (we ignore location here).
The temporal trace function τ is a partial function from worlds and events into periods:

$$\tau: E \times W \rightarrow I$$

τ specifies the running time of events in worlds.

So: if $e \in$ PURR and Ag(e)= RONYA and $\tau(e,w) \neq \bot$, then world w contains at some interval of time an event of Fred walking.

We assume that τ links the verbal predicates to the world w. So, we do not assume that the verb predicates have themselves a world variable $HUG_w(e)$, the world variable is provided via τ.

We are not forcing nouns into the Neo-Davidsonian format here (though some people propose that too). This means that we **do** assume for nouns a world index.

Thus, we interpret nouns as relations between individuals and worlds:

cat $\quad CAT \in CON_{<s,<e,t>>}$

Just to get the flavor of it, ultimately, we will interpret (1a) as (1b):

(1) a. A senator stabbed Caesar
b $\exists e[\ STAB(e) \wedge \exists x[SENATOR_w(x) \wedge Ag(e) = x] \wedge Th(e) = CAESAR \wedge$
$\tau(e,w) < \mathbf{now}\ ]$

There is a stabbing event with as agent someone who is a senator in w and as theme Caesar, and that stabbing event is located in w before now.

The grammar:
Verbs: $<e^n,<\eta,t>>$,
where $<e^1,a> = <e,a>$
$<e^2,a> = <e,<e,a>>$
$<e^3,a> = <e,<e,<e,a>>>$

Transitive verbs
Lexical item: *hug*
type: $<e,<e,<\eta,t>>>$
Interpretation: $\lambda y\lambda x\lambda e.HUG(e) \wedge Ag(e)=x \wedge Th(e)=y$

Intransitive verbs
Lexical item: *purr*
type: $<e,<\eta,t>>$
Interpretation: $\lambda x\lambda e.PURR(e) \wedge Ag(e)=x$

Inflection
Lexical Item: Past tense *-ed*

type: $<<e,<\eta,t>>, <e,<\eta,t>>>$
Interpretation: $\lambda V\lambda x\lambda e.V(e,x) \wedge \tau(e,w) <$ **now**   where $V \in VAR_{<e,<\eta,t>>}$

Nouns:
Lexical item: *cat*
type: $<s,<e,t>>$
interpretation: CAT_w

Determiners: as before

At the IP level we derive a type $<\eta,t>$.
We assume that the interpretation of the complementizer C requires (minimally) a t-input (when necessary lifted to $<s,t>$).
We add default existential closure to the type shifting theory:

Existential closure
EC: $<\eta,t> \rightarrow t$
$EC[\alpha] = \exists e[\alpha(e)]$ (in other words: $\alpha \neq \emptyset$).

In-situ application enters noun phrase interpretations into event types
Let α be a verbal or inflectional interpretation of type $<e^n,<\eta,t>>$ and β a nounphrase interpretation.

Resolving APPLY[α, β] without storage we call *in situ application*.

We will need new type shifting rules for this.

Type shifting rules:

Observation: what was a one-place predicate before is now a two-place predicate.
So we apply the type shifting principle we had for two-place predicates to what was the one-place predicate. Similarly, we generalize to three-place predicates:

LIFT: $<\mathbf{e},<e,<\eta,t>>> \rightarrow <\mathbf{<<e,t>,t>},<e,<\eta,t>>>$
$LIFT[\alpha] = \lambda T\lambda x\lambda e.T(\lambda y.\alpha(e,x,y))$

LIFT: $<\mathbf{e},<\eta,t>> \rightarrow <\mathbf{<<e,t>,t>},<\eta,t>>$
$LIFT[\alpha] = \lambda T\lambda e.T(\lambda x.\alpha(e,x))$

Scopal problems in the Davidsonian theory:

Event type principle (See extensive discussion in Landman 2000)
Non-scopal noun phrases can be entered into event types, definites, indefinites
Scopal noun phrases cannot be entered into event types. quantificational, every, most
Negation cannot be entered into events types

This means in the sample grammar we give here that scopal noun phrases must be stored and retrieved.

Retrieval: Retrieval takes place as before at type t.

Consequence: retrieval takes place after event existential closure.

-Extensions to the theory of plurality, see below.

Adverbials: $<\eta,t>$
Prepositions: $<e,<\eta,t>>$

Typeshifting:

LIFT: $<\eta,t> \rightarrow <<e^n, <\eta,t>>,<e^n, <\eta,t>>>$

$\text{LIFT}[\alpha] = \lambda\Pi\lambda x_n\ldots\lambda x_1\lambda e.\Pi(e,x_1,\ldots x_n) \wedge \alpha(e)$

The theory presented here satisfies Parson's Unique Role Requirement:

Unique Role Requirement:
If a thematic role is realized for an event, it is uniquely realized:
Thematic roles are partial functions from events to event participants (like individuals)

Examples (Parsons)

(1) Brutus stabbed Caesar in the back with a knife

stab $\rightarrow \lambda y\lambda x\lambda e.\text{STAB}(e) \wedge \text{Ag}(e)=x \wedge \text{Th}(e)=y$
stabbed $\rightarrow \lambda y\lambda x\lambda e.\text{STAB}(e) \wedge \text{Ag}(e)=x \wedge \text{Th}(e)=y \wedge \tau(e,w) < \text{now}$
stabbed Caesar $\rightarrow \lambda x\lambda e.\text{STAB}(e) \wedge \text{Ag}(e)=x \wedge \text{Th}(e)=\text{CAESAR} \wedge \tau(e,w) < \text{now}$

with $\rightarrow \lambda x\lambda e.\text{WITH}(e)=x$
shift *with* to: $\lambda T\lambda e.T(\lambda x.\text{WITH}(e)=x)$
with a knife $\rightarrow \lambda e.\exists x[\text{KNIFE}_w(x) \wedge \text{WITH}(e)=x]$ $<\eta,t>$

Shift to: $\lambda R\lambda x\lambda e.R(e,x) \wedge \exists x[\text{KNIFE}_w(x) \wedge \text{WITH}(e)=x]$ $<e, <\eta,t>>$

stabbed Caesar with a knife $\rightarrow$
$\lambda x\lambda e.\text{STAB}(e) \wedge \tau(e,w) < \text{now} \wedge \text{Ag}(e)=x \wedge \text{Th}(e)=\text{CAESAR} \wedge \exists x[\text{KNIFE}_w(x) \wedge \text{WITH}(e)=x]$

in $\rightarrow \lambda x\lambda e.\text{IN}(e)=x$
in the back $\rightarrow \lambda e.\text{IN}(e)=\sigma(\lambda x.\text{BACK}_w(x,\text{Th}(e)))$ $<\eta,t>$
Shift to: $\lambda R\lambda x\lambda e.R(x,e) \wedge \text{IN}(e)=\sigma(\lambda x.\text{BACK}_w(x,\text{Th}(e)))$

stabbed Caesar with a knife in the back $\rightarrow$
$\lambda x\lambda e.\text{STAB}(e) \wedge \tau(e,w) < \text{now} \wedge \text{Ag}(e)=x \wedge \text{Th}(e)=\text{CAESAR} \wedge$
$\exists z[\text{KNIFE}_w(z) \wedge \text{WITH}(e)=z] \wedge \text{IN}(e)=\sigma(\lambda x.\text{BACK}_w(x,\text{Th}(e)))$
=

$\lambda x\lambda e.STAB(e) \wedge \tau(e,w) < now \wedge Ag(e)=x \wedge Th(e)=CAESAR \wedge$
$\exists z[KNIFE_w(z) \wedge WITH(e)=z] \wedge IN(e)=\sigma(\lambda x.BACK_w(x,CAESAR))$

Brutus stabbed Caesar with a knife in the back →
$\lambda e.STAB(e) \wedge \tau(e,w) < now \wedge Ag(e)=BRUTUS \wedge Th(e)=CAESAR \wedge$
$\exists z[KNIFE_w(z) \wedge WITH(e)=z] \wedge IN(e)=\sigma(\lambda x.BACK_w(x,CAESAR))$

Existential closure:

Brutus stabbed Caesar with a knife in the back
$\exists e[STAB(e) \wedge \tau(e,w) < now \wedge Ag(e)=BRUTUS \wedge Th(e)=CAESAR \wedge$
$\exists z[KNIFE_w(z) \wedge WITH(e)=z] \wedge IN(e)=\sigma(\lambda x.BACK_w(x,CAESAR))]$

Brutus stabbed Caesar with an icepick in the front
$\exists e[STAB(e) \wedge \tau(e,w) < now \wedge Ag(e)=BRUTUS \wedge Th(e)=CAESAR \wedge$
$\exists z[ICEPICK_w(z) \wedge WITH(e)=z] \wedge IN(e)=\sigma(\lambda x.FRONT_w(x,CAESAR))]$

Two simultaneous stabbings.

8.4. Passives and the Unique Role requirement[from Landman 2000]

The classical theory of passives (eg. Partee 1967,Dowty 1982) is as follows. Passivisation is an operation that takes a transitive VP (type $<e,<e,t>>$ and gives you a passive intransitive VP (type $<e,t>>$ Semantically, Passivisation existentially quantifies over the innermost argument in the A-prefix:

PASS: $<e,<e,t> \rightarrow <e,t>$
PASS$[\lambda y\lambda x.R(x,y)] = \lambda y.\exists x[R(x,y)]$

be hugged → PASS[HUG]
$= \lambda y.\exists x[HUG(x,y)]$

Consequently, (15a) becomes (15b):

(15) a. Ronya was hugged.
b. $\exists x[HUGx,RONYA)]$

This straightforward analysis leads to a problem with passives which have the *by*-phrase explicitly expressed:

(16) Ronya was hugged by Anna.

The meaning of the passive VP in (17a) is (17b). With the meaning of the *by*-phrase, we would want (17d) to be the meaning of (17c):

(17) a. Was hugged
b. $\lambda y.\exists x[HUG(x,y)]$
c. Was hugged by Anna
d. $\lambda y.HUG(ANNA,y)$

We can see the problem more clearly if we represent (37d) in the equivalent form (17e):

(17) e. $\lambda y.\exists x[HUG(x,y) \wedge x=ANNA]$

We would like the meaning of the *by*-phrase to produce meaning (17e) out of the meaning of the passive verb (17b). The problem is that in the classical theory this is impossible, because there is no compositional way of getting x=ANNA inside the scope of the existential quantifier.

The classical solution is to assume that in fact there are two operations of passivisation: one for the case where the *by*-phrase is not expressed -which is the operation we have given, and another for the case where it is. So, we add a second rule of passivisation:

Passivisation-2 turns an agentive transitive VP into a passive transitive VP by turning the arguments around:

$PASS_2$: <e,<e,t>> → <e,<e,t>>
$PASS_2[\lambda y \lambda x.R(x,y)] = \lambda x \lambda y.R(x,y)$

be hugged → $PASS_2[HUG]$
$= \lambda x \lambda y.HUG(x,y)$

The meaning of the *by*-phrase, *by* NP, is just the meaning of the NP, and a further rule tells us that a passive transitive VP and a *by*-phrase combine by functional application to form a passive intransitive VP:

TV_{pass} + *by* NP → VP_{pass}
INTERPRETATION:
TV' NP' APPLY[TV' ,NP']
be hugged by Anna → $([\lambda x \lambda.HUG(x,y)](ANNA)$
$= \lambda y.HUG(ANNA,y)$

This finally gives us:

(18) a. Ronya was hugged by Anna.
b. HUG(ANNA, RONYA)

Now, this may not be very elegant, but in the classical theory you don't have much of a choice, because, as indicated, the standard rule of passivisation existentially quantifies over the subject, which thereby becomes inaccessible.
The situation is as follows: we have a passive predicate $\lambda y.\exists x[HUG(x,y)]$ and the contribution of the *by*-phrase: x=ANNA. In the latter, x is a free variable and we want to be able to get it bound by the quantifier.

This situation is similar to cases described by Dekker 1993 and Chierchia 1995. Dekker 1993 introduces an operation of ' existential disclosure' which, within dynamic semantics, is able· to open up the scope of an existential quantifier (see also Chierchia 1995 for applications). In such a dynamic framework we would need only one rule of passivisation and we can assume that the rule combining a passive VP with the by-phrase applies existential disclosure to the passive VP meaning and then adds the meaning of the by-phrase. I will not develop a dynamic semantics here further, but rather, I will show that in the neo-Davidsonian theory, we can get the same effect without having to rely on dynamic binding.

The operation of passivisation I will assume is just the standard rule of existentially binding the subject argument:

> **Passivisation:**
> PASS: $<e,<e,<\eta,t>>> \rightarrow <e,<\eta,t>>$
> Let $R \in <e,<e,<\eta,t>>>$
> $PASS[R] = \lambda y \lambda e \exists x[R(e,x,y)]$

We derive:

hug $\rightarrow \lambda y \lambda x \lambda e.\ HUG(e) \wedge Ag(e)=x \wedge Th(e)=y$
was hugged $\rightarrow PASS[\lambda y \lambda x \lambda e.\ HUG(e) \wedge Ag(e)=x \wedge Th(e)=y]$

$PASS[\lambda y \lambda x \lambda e.\ HUG(e) \wedge Ag(e)=x \wedge Th(e)=y] =$
$\lambda y \lambda e \exists x[HUG(e) \wedge Ag(e)=x \wedge Th(e)=y]$

was kissed $\rightarrow \lambda y \lambda e \exists x[HUG(e) \wedge Ag(e)=x \wedge Th(e)=y]$

Applying the passive VP to the subject *Ronya*, we get, after existential closure:

(19) a. Ronya was hugged.
b. $\exists e[HUG(e) \wedge \exists x[Ag(e)=x \wedge Th(e)=RONYA]$

We can now treat the *by*-phrase as a VP-adverbial. Semantically, it is a normal Davidsonian adverbial. Syntactically, it will have some restrictions: it can only modify passive VPs, and passive VPs can have only one such modifier. The meaning of the *by* phrase is what we would expect on the neo-Davidsonian theory: it adds whatever role is appropriate as a subject for the verbal head, usually an agent:

Agentive *by*-phrase:
*b*y $\rightarrow \lambda x \lambda V \lambda y.V(e,y) \wedge Ag(e)=x$
by Anna $\rightarrow \lambda V \lambda y.V(e,y) \wedge Ag(e)=ANNA$

Normal application gives:

(20) a. *be hugged by Anna*
b. $\lambda y \lambda e.\ HUG(e) \wedge \exists x[Ag(e)=x \wedge Th(e)=y] \wedge Ag(e)=ANNA$

We see that in (20b) the agent expression contributed by the by-phrase is not in the scope of the existential quantifier introduced by the passive.
However, that doesn't matter since: for every object y, the set of hugging events with y as theme and something as agent and Anna as agent is identical to the set of hugging events with y as agent and Anna as agent.
Thus, (20b) is equivalent to (2Oc):

(20) a. *be hugged by Anna*
c. $\lambda y \lambda e.HUG(e) \wedge Ag(e)=ANNA \wedge Th(e)=y$

This is even more obvious when we assume the Unique Role Requirement, since then the 'someone' is obviously required to be identical with John. However, the argument doesn't depend on the Unique Role Requirement (the argument for the Unique Role Requirement comes below).

With (20c), we derive:

(21) a. Ronya was hugged by Anna.
b. $\exists e[HUG(e) \wedge Ag(e)=ANNA \wedge Th(e)=RONYA]$

Thus, the neo-Davidsonian theory allows for a very simple and elegant treatment of passive:
- We need only one rule of passivisation, and its interpretation is standard:
existential closure of the agent argument of the agentive transitive verb.
- By-phrases are adverbials and get the semantics of adverbials, adding a second agent specification to the passive VP besides the one that is existentially quantified over.
- Since the second agent specification will entail the existentially quantified agent specification, the existentially quantified agent specification is redundant.

I think that this is a powerful and very useful aspect of the Davidsonian theory

(Note that I have restricted myself here to cases of agentive transitive verbs where the by-phrase adds the agent. Of course, we can allow the by-phrase to add other roles for non-agentive transitive verbs that nevertheless allow passivisation.)
I am assuming that the by-phrase is an adverbial modifier of passive VPs. This means that the by-phrase gets added to the VP after passivisation.

We observe the following: in the classical analysis verbs are analyzed as n-place relations:

$\lambda x_n \ldots \lambda x_1.V(x_1, \ldots ,X_n)$

Applying an n-place relation to an argument, say, a generalized quantifier T, results in an n−1-place relation:

$\lambda x_{n-l} \ldots \lambda x_l.T(\lambda x_n.V(x_1, \ldots ,x_n))$

More in particular, existentially closing the n-th argument gives:

$\lambda x_{n-1} \ldots \lambda x_1.\exists X_n[V(x_1, \ldots ,X_n)]$

After we have applied the verb to the argument, we have a set of n−l tuples, and from this denotation we cannot reconstruct the original n-th argument of the verb. This means that the original n-th argument has become semantically inaccessible.

In the neo-Davidsonian approach, we interpret the verb as an n-place event type:

$\alpha = \lambda x_n \ldots \lambda x_1 \lambda e.V(e) \wedge R_1(e)=x_1 \wedge \ldots \wedge R_n(e)=x_n$

In this interpretation the arguments of the verb are represented explicitly: we have a function from n arguments into an event type. If we do existential closure over the n-th argument, the n-th argument is no longer represented explicitly: we have a function from n–l arguments into a set of events:

$EC[\alpha.R_n] = \quad \lambda x_{n-l} \ldots \lambda x_l \lambda e.\exists x_n[\alpha(e,x_1,\ldots,x_n)]$

$\beta = \lambda x_{n-l} \ldots \lambda x_n \lambda e.\ V(e) \wedge R_l(e)=x_l \wedge \ldots R_{n-l}(e)=x_{n-l} \wedge \exists x_n[R_n(e)=x_n]$

While the n-th argument is no longer explicitly represented, it is implicitly still there and can be semantically accessed through the role that the n-th argument fills. Thus, existentially closing an individual argument in an n-place event type makes that argument implicit. The fact that the implicit argument is not inaccessible is shown by the fact that we can defme an operation - which we can call predication - which makes the argument explicit:

$PRED[\beta,R_n] = \quad \lambda x_n \lambda x_{n-l} \ldots \lambda x_1 \lambda e.\ \beta(x_1,\ldots,x_{n-l})) \wedge R_n(e)=x$

These operations are inverses:

$PRED[EC[\alpha,R_n],R_n] = \alpha$
$EC[PRED[\beta,R_n],R_n] = \beta$

Thus the Davidsonian theory is a natural framework for defining operations which suppress explicit arguments or express implicit arguments.

7.4. Event structures for plurality
Link 1987, Krifka 1989, Landman 1994, 2000

E = <E, ⊑, ⊔, $\text{ATOM}_\mathbf{E}$> is a complete atomic Boolean algebra, a structure of singular events (atoms) and pluralities.

Thematic roles are partial functions from events to individuals.

In particular:

Thematic roles are partial functions from **singular events** to **singular individuals**

$\text{Ag}: \text{ATOM}_\mathbf{E} \rightarrow \text{ATOM}_\mathbf{D}$
$\text{Th}: \text{ATOM}_\mathbf{E} \rightarrow \text{ATOM}_\mathbf{D}$ etc.

Plural roles are partial functions from (singular and plural) events to (singular and plural) individuals:

$^*\text{Ag}: \text{E} \rightarrow \text{D}$
$^*\text{Th}: \text{E} \rightarrow \text{D}$ etc.

$$^*\text{Ag}(e) = \begin{cases} \sqcup\{\text{Ag}(e'): e' \in \text{AT}_e\} & \text{if for every } e' \in \text{AT}_e\text{: Ag}(e') \neq \perp \\ \perp & \text{otherwise} \end{cases}$$

***Example* 1**

Let $\text{PURR} \subseteq \text{ATOM}_\text{E}$ and let $e_1, e_2, e_3 \in \text{PURR}$
Let $\text{CAT}_w \subseteq \text{ATOM}_\text{D}$ and let EMMA, PIM, SASHA $\in \text{CAT}_w$
Let: $\text{Ag}(e_1) = \text{EMMA}$, $\text{Ag}(e_2) = \text{PIM}$, $\text{Ag}(e_3) = \text{SASHA}$

Then: $\text{PURR}(e_1) \wedge \text{Ag}(e_1)=\text{EMMA}$
$\text{PURR}(e_2) \wedge \text{Ag}(e_2)=\text{PIM}$
$\text{PURR}(e_3) \wedge \text{Ag}(e_3)=\text{SASHA}$

Then: $^*\text{PURR}(e_1 \sqcup e_2 \sqcup e_3) \wedge {}^*\text{Ag}(e_1 \sqcup e_2 \sqcup e_3)= \text{EMMA} \sqcup \text{PIM} \sqcup \text{SASHA}$

Then: $^*\text{PURR}(e_1 \sqcup e_2 \sqcup e_3) \wedge \exists x[{}^*\text{CAT}_w(x) \wedge |x|=3 \wedge {}^*\text{Ag}(e_1 \sqcup e_2 \sqcup e_3)= x]$

Then: $\exists e[{}^*\text{PURR}(e) \wedge \exists x[{}^*\text{CAT}_w(x) \wedge |x|=3 \wedge {}^*\text{Ag}(e)= x]$

Or equivalently: $\exists e[{}^*\text{PURR}(e) \wedge {}^*\text{CAT}_w({}^*\text{Ag}(e)) \wedge |{}^*\text{Ag}(e)| = 3]$
Three cats purr

We derive the distributive reading of *three cats purr* via semantic plurality of plural role *Ag.

Example 2

Let $HUG \subseteq ATOM_E$, let $e_1, e_2, e_3 \in HUG$
Let $GIRL_w \subseteq ATOM_D$, let LEE, KIM, SAM $\in GIRL_w$
Let $CAT_w \subseteq ATOM_D$, let EMMA, SASHA $\in CAT_w$

Let: $Ag(e_1) = LEE$, $Ag(e_2) = KIM$, $Ag(e_3) = SAM$
Let: $Th(e_1) = EMMA$, $Th(e_2) = EMMA$, $Th(e_3) = SASHA$

Then:

$HUG(e_1) \wedge Ag(e_1) = LEE \wedge Th(e_1) = EMMA$
$HUG(e_2) \wedge Ag(e_2) = KIM \wedge Th(e_2) = EMMA$
$HUG(e_3) \wedge Ag(e_3) = SAM \wedge Th(e_3) = SASHA$

Hence, by definition of *HUG and *Ag and *Th:

$$*HUG(e_1 \sqcup e_2 \sqcup e_3) \wedge *Ag(e_1 \sqcup e_2 \sqcup e_3) = LEE \sqcup KIM \sqcup SAM \wedge$$
$$*Th(e_1 \sqcup e_2 \sqcup e_3) = EMMA \sqcup SASHA$$

Hence:

$$\exists e[*HUG(e) \wedge *Ag(e) = LEE \sqcup KIM \sqcup SAM \wedge *Th(e) = EMMA \sqcup SASHA]$$

and:

$$\exists e[*HUG(e) \wedge \exists x[*GIRL_w(x) \wedge |x|=3 \wedge *Ag(e) = x] \wedge \exists y[*CAT_w(y) \wedge |y|=2 \wedge *Th(e) = y]]$$

of equivalently

$$\exists e[*HUG(e) \wedge *GIRL_w(*Ag(e)) \wedge |*Ag(e)|= 3 \wedge *CAT_w(*Th(e)) \wedge |*Th(e)|=2$$

Three girls hug two cats

We derive the cumulative reading of *three cats purr* via simultaneous, non-scopal semantic plurality of plural roles *Ag and *Th.

Thus cumulativity is the generalization of semantic plurality from one-place predicates to n-place relations, n roles are pluralized simultaneously and scopally independently.

The latter means:

$$\exists e[*HUG(e) \wedge \exists x[*GIRL_w(x) \wedge |x|=3 \wedge *Ag(e) = x] \wedge \exists y[*CAT_w(y) \wedge |y|=2 \wedge *Th(e) = y]]$$

There is no scopal dependency relation between the interpretatrion of the two DPs filling the two argument places of the relation in the cumulative interpretation.

Hence: a unified theory of distributivity and cumulativity.

Further topics:
-cumulative readings for non-upward entailing DPs: See Landman 2000, 2004.
-the debate on cover roles between Landman and Roger Schwarzschild, see Landman 2000 for references.

Let R be a thematic role, we define a cover role ${}^{C}R$ based on R:

$$ {}^{C}R = \begin{cases} a & \text{if } a \in \text{ATOM and } \sqcup\{\downarrow d \in {}^{*}\text{IND}: d \in \text{ATOM}_{{}^{*}R(e)}\} = \downarrow a \\ \\ \perp & \text{otherwise} \end{cases} $$

Landman 2000 assumes that, by default, lexical roles of verbs are plural roles, but he allows a mechanism that shifts plural roles to cover roles under certain circumstances.

Schwarzschild assumes that, by default, all lexically roles of verbs are cover roles.

(1) a. The cats carried their ball upstairs
  b. The cats chased the dogs

For Landman (1a) is, out of the blue, ambiguous between a collective reading: the group of cats carried the ball upstairs, or a distributive reading: each individual cat carried the ball upstairs.
With shift to cover readings, you can get intermediate readings, like: the cats divide into two groups, each of which carried the ball upstairs.

Ignoring scopal readings, (1b) has several readings for Landman: a double distributive reading: the group of cats chases the group of dogs, a cumulative reading: individual cats chased individual dogs, summing up all in all to the cats and the dogs. And two scopeless collective-distributive, distributive-collective readings: the group of cats chased four dogs individually, or four individual cats chased the group of dogs.

With cover shift you get more readings: for instance: cumulative on subgroups:
the cats divide into two groups and the dogs into two, and the first group of cats chases the first group of dogs and the second group of cats chased the second group of dogs.

On Landman's theory the collective-distributive and double collective and cumulative are the central most prominent readings, cover readings you can force in appropriate contexts.

Schwarzschild's theory is simultaneously more economic and less economic. It makes the lexical entries much more complex and semantically much weaker.
But as a consequence it takes the ambiguity out of the theory completely:

Three cats carry the ball upstairs →
$\exists e[{}^{*}\text{CARRY}(e) \wedge \exists x[{}^{*}\text{CAT}_{w}(x) \wedge {}^{C}\text{Ag}(e) = \uparrow x]]$
There is a sum of carrying the ball upstairs events and sum of three cats and there is a set of subgroups of that sum of cats (where individuals count as subgroups) such that each of those subgroups carries the ball upstairs.

The distributive and the collective readings are instances of this reading, but so are readings distributing to intermediate subgroups.

Three cats chase two dogs →
$\exists e[{}^*\text{CHASE}(e) \wedge \exists x[{}^*\text{CAT}_w(x) \wedge |x|=3 \wedge {}^C\text{Ag}(e)=\uparrow x] \wedge \exists y[{}^*\text{DOG}_w(y) \wedge {}^C\text{Th}(e)=\uparrow y]]$

Here too, the sentence says that there is a set of subgroups of a sum of three cats and there is a set of subgroups of a sum of two dogs, and the each of the cat subgrous is the agent of one of the chase events and each of the dog subgroups is the theme of one of the chase events.

The double collective and the cumulative readings are instances of this reading, and so are all intermediate distribution to blocks in a cover reading.
So there is only one scopeless reading.

Problems with this discussed in Landman 2000:
-the connection between collectivity and singularity is lost.
-the theory predicts that covering is the standard case, predicting much more covering than is actually found.

But the debate has continued since.