Aspect, plurality and quantification*

Handout for the dissertation proposal defense by

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1 Scope of inquiry

1.1 Internal arguments, external arguments, and adjuncts

We start with a question of hopefully general interest:

(1) What is the meaning of love?

Despite decades of research, semanticists faced with (1) are as clueless as everyone else. Even restricting our attention to verbal denotations, the correct answer is a subject of debate:

(2) $[\![\text{love}]\!] =$

a. $\lambda y.\lambda x.\text{love}'(x, y)$ (textbook answer)

b. $\lambda y.\lambda x.\lambda e.[\text{love}'(e) \wedge \text{theme}(e) = x \wedge \text{agent}(e) = y]$ (event semantics)

c. $\lambda x.\lambda e.[\text{love}'(e) \wedge \text{agent}(e) = x]$ (no one, really)

d. $\lambda y.\lambda e.[\text{love}'(e) \wedge \text{theme}(e) = y]$ (Kratzer, 1996)

e. $\lambda e.\text{love}'(e)$ **(radical neo-Davidsonian view, this proposal)**[1]

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[1] Also Beaver and Condoravdi (2007), but they reconstruct events using partial functions from role names to individuals.

More generally, how do arguments and adjuncts combine their meaning with the verb? Do internal and external arguments behave the same in this respect? Can syntactic and semantic differences between internal and external arguments (e.g. ability to form idiom chunks, ability to determine the meaning of polysemous verbs) be traced to verbal denotations? What about differences between arguments and adjuncts?

> ***Hypothesis 1:*** The answer to (1) is (2e). As far as verbal denotations go, there is no difference between internal arguments, external arguments, and adjuncts, contra Kratzer (1996). Arguments and adjuncts combine with the verb via thematic role heads. Any observable differences must be due to syntax or other factors.

1.2 Distributivity

Distributivity is a pervasive phenomenon in language. Here are two parts of the grammar in which it occurs:

Quantificational noun phrases (QNPs)

(3) Six girls (each) got two flowers.
Paraphrase: Six girls are such that each of them got two flowers.

Durative adverbials

(4) The President spoke for an hour.
Paraphrase: An hour is such that at each of its moments the President spoke.

It is currently unsettled what the source of distributivity in natural language is, and whether all instances of distributivity are fundamentally alike or whether it occurs in different, unrelated shapes.

> ***Hypothesis 2:*** There is only one kind of distributivity. The properties of distributivity can be captured by postulating a single operator.

1.3 *for*-adverbials

As is well known, *for*-adverbials are sensitive to the aspectual properties of the predicate they modify:

(5) a. John ate apples for an hour.
b. *John ate an apple for an hour.
c. *John ate two apples for an hour.

d. John pushed carts for an hour.
e. John pushed a cart for an hour.
f. John pushed two carts for an hour.

There is still no consensus on what exactly causes some predicates to be compatible with *for*-adverbials and others not: Does *for* require the predicate to distribute over subevents (Krifka, 1998) or subintervals (Dowty, 1979; Moltmann, 1991)?

Hypothesis 3: *for*-adverbials contain the distributivity operator, which distributes the predicate over subintervals, not subevents, contra Krifka (1998).

1.4 Methodological goals

Besides testing the hypotheses above, this dissertation aims to:

- Provide a unified framework for the treatment of verb-argument interactions, especially cumulative and distributive readings of quantifiers and aspectual phenomena, subsuming and expanding previous landmark frameworks by Krifka (1998) and Landman (2000).
- Shed light on the compositional process by which arguments and adjuncts are associated with events.
- Unify existing mereological semantic theories in this framework and check their mutual compatibility.
- Generalize event-based treatments of distributivity between noun phrases such as (Landman, 2000, ch. 6) to sentences with more than two quantifiers.
- Provide an event-based semantics for LTAG (Joshi et al., 1975) and for its NLP-friendly variant LTAG-spinal (Shen, Champollion, and Joshi 2008).

An important part of this proposal is getting the compositional process, i.e. the derivations right. This handout does not display any derivations. Please refer to the written proposal for them.

2 Common properties of distributivity across domains

2.1 The whole event or situation can be modified

(6) Unharmoniously, every musician played for fifteen minutes.

Incorrect paraphrase: A fifteen-minute timespan is such that at each of its moments every musician played unharmoniously.
Better paraphrase: A fifteen-minute timespan is such that at each of its moments every musician played and **the whole event or situation** was unharmonious.

(7) Three boys gave six girls two flowers (each).
Incorrect paraphrase: Six girls each got two flowers, and in each event, three boys were the sum total of the agents involved.
Better paraphrase: Six girls each got two flowers, and three boys were the sum total of the agents involved in **the whole event or situation**.

2.2 Pragmatics influences which cases are distributed over

(8) The President and the First Lady waltzed for an hour.
Incorrect paraphrase: An hour is such that at each of its moments, the President and the First Lady waltzed.
Better paraphrase: An hour is such that at each of its **relevant subintervals**, the President and the First Lady waltzed. (Minimal parts problem: Dowty, 1979)

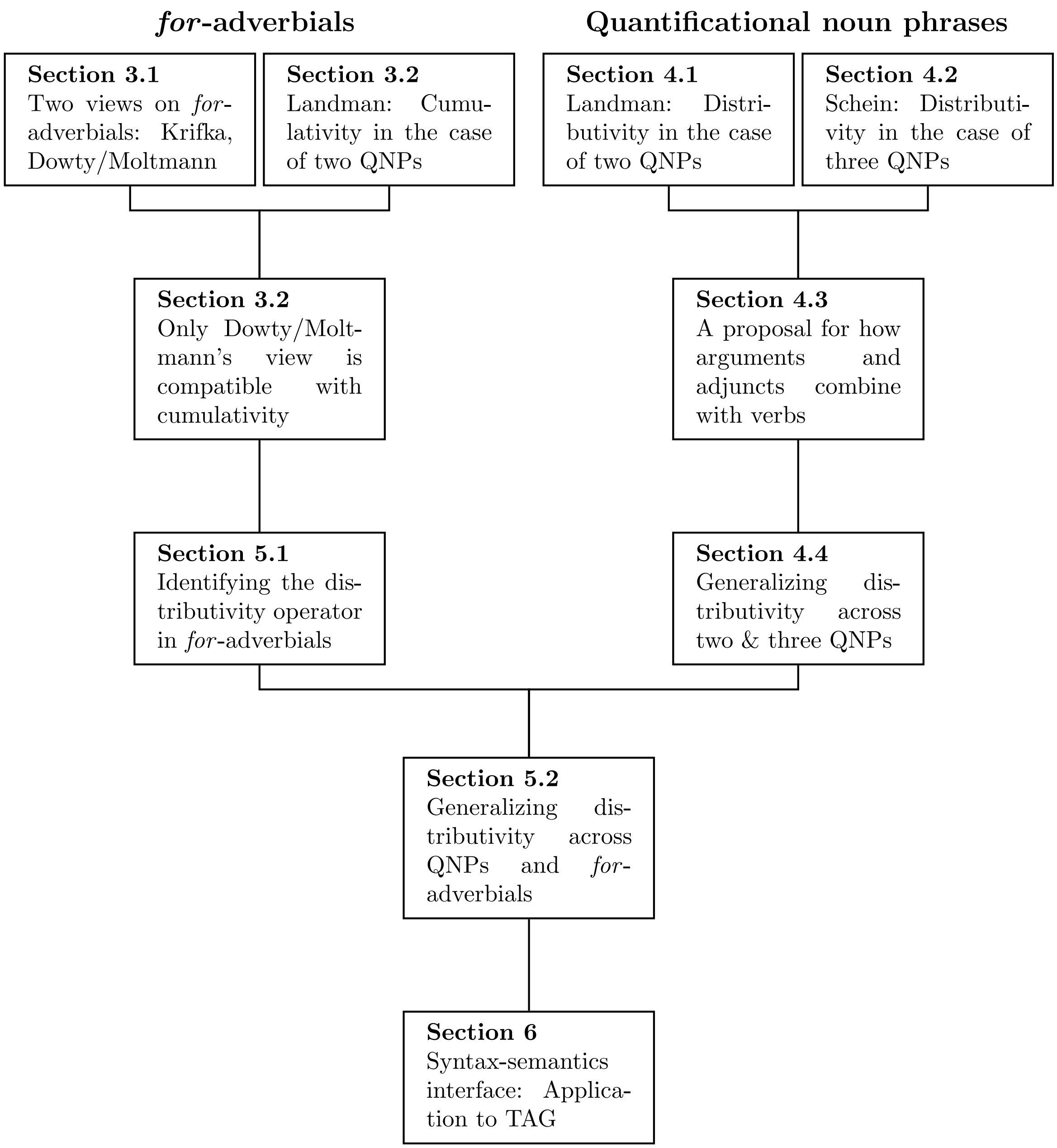
Scenario: Last year, Groenendijk and Stokhof got a joint Spinoza Prize for their dissertation, and Johan van Benthem got a Spinoza Prize for his life's work.

(9) Last year, three Dutch professors received a Spinoza prize in linguistics.
Incorrect paraphrase: Three Dutch professors are such that each of them got a Spinoza prize.
Better paraphrase: A sum total of Dutch professors are such that each of its **relevant subparts** got a Spinoza prize. (Schwarzschild, 1991, 1996)

Previous accounts either do not model these properties at all or do not explain their similarity. This proposal explains the similarities between distributivity in different domains by tracing nominal and adverbial distributivity to the same operator.

2.3 Plan of the argument

Section numbers from here on are the same as in the written proposal, so this plan applies both to this handout and to the written proposal.



3 Cumulative readings help pin down *for*-adverbials

3.1 Two views on *for*-adverbials: Krifka, Dowty/Moltmann

Common idea in explanations since at least Dowty (1979): *for*-adverbials require the predicate they modify to be true of some smaller parts. But they disagree on what these are smaller parts of.

- Krifka (1998): *for*-adverbials distribute over subevents
- Dowty (1979); Moltmann (1991): *for*-adverbials distribute over subintervals

We will see that Krifka (1998) is incompatible with cumulative readings. But first, let's look at each theory in turn.

Events, individuals, and time intervals are each assumed to be ordered in mereological structures. For any entities e, e', e'' in one of these domains, we write $e \leq e'$ to say that e is part of e', and $e = e' \oplus e''$ to say that e is the sum of e' and e''. These notions can be defined in terms of each other, e.g. we can take $\oplus$ as primitive and write $e \leq e'$ just in case $e \oplus e' = e'$. We write $e < e'$ for $e \leq e' \wedge e \neq e'$. Each of these domains is assumed to be closed under sum. Instead of "part of" we also say "subevent of" or "subinterval of" etc.

Krifka's entry

(10) $[\![\text{for an hour}_{Krifka}]\!]_{\langle\langle e,vt\rangle,\langle e,vt\rangle\rangle}$
Assertion: $\lambda R_{\langle e,vt\rangle}\lambda x_e \lambda e_v.R(x)(e) \wedge H'(e) = 1$
Presupposition: $\partial\exists e'[e' <_{H'} e] \wedge \forall e''[e'' \leq_{H'} e \rightarrow R(x)(e'')]$

How to read this:

(11) **Translation of *for an hour* according to Krifka**

1	$\lambda R_{\langle e,vt\rangle}.$	1^{st} argument: the verb phrase R
2	$\lambda x_e.$	2^{nd} argument: the subject x
3	$\lambda e_v.$	3^{rd} argument: the sum event e (from closure)
4	$R(x)(e)$	There is an event of which $R(x)$ holds
5	$\wedge H'(e) = 1$	The duration of the event is one hour
6	$\wedge\ \partial\exists e'[e' <_{H'} e]$	Presupp.: The event has shorter subevents ...
7	$\wedge\ \forall e''[e'' \leq_{H'} e \rightarrow R(x)(e'')]$	... and $R(x)$ holds of each shorter subevent

Example:

(12) John played the piano for an hour.

(13)

	Translation of (12)	
1	$\exists e.\text{play-piano}'(e, john)$	There is an event of John playing the piano
2	$\wedge H'(e) = 1$	The duration of the event is one hour
3	$\wedge\ \partial\exists e'[e' <_{H'} e]$	Presupp.: The event has shorter subevents ...
4	$\wedge\ \forall e''[e'' \leq_{H'} e \rightarrow$	... and all its shorter subevents ...
5	$\text{play-piano}'(e'', john)]$	... are also events of John playing the piano.

This entry will reject VPs like *eat two apples*, because an event to which *eat two apples* applies has no shorter subevents which would again fall under the denotation of *eat two apples*. But VPs like *play the piano*, *eat apples* or *push a cart* apply to events and their subevents, so they are not rejected.

Entry based on Dowty and Moltmann

Dowty (1979) provides an entry that is not based on event semantics. Moltmann (1991) adapts his views into an event semantic framework but doesn't provide an entry. This entry is extrapolated from her article.

(14) $[\![\text{for an hour}_{Dowty/Moltmann}]\!]_{\langle\langle e,vt\rangle,et\rangle}$
$= \lambda R_{\langle e,vt\rangle}\lambda x_e.\ \exists t\ [H(t) = 1]$
$\wedge\ \forall t'\ [t'\text{P}t \rightarrow \exists e\ [R(x)(e) \wedge \tau(e) = t']]$

How to read this:

(15)

	Translation of *for an hour* according to Moltmann	
1	$\lambda R_{\langle e,vt\rangle}.$	1^{st} argument: the VP
2	$\lambda x_e.$	2^{nd} argument: the subject
3	$\exists t\ [H(t) = 1]$	There is an interval t that lasts one hour
4	$\wedge\ \forall t'\ [t'\text{P}t \rightarrow$	At each relevant subinterval t' ...
5	$\exists e.$	... there is an event ...
6	$[R(x)(e)$	... of which the sentence holds ...
7	$\wedge\ \tau(e) = t']]$	... and that takes place at t'

Note the relation $t'\text{P}t$, which is to be read as: t' is a relevant subinterval of t. The relation P is supposed to be supplied by context. We'll discuss constraints on P later.

Example:

(16) John played the piano for an hour.

	Translation of (16)		
	1	$\exists t\ H(t) = 1$	There is a time interval t that lasts an hour
(17)	2	$\wedge\ \forall t'[t'\mathrm{P}t \rightarrow$	At each relevant subinterval t' ...
	3	$\exists e$ [play-piano$'(e, john)$	...there is an event of John playing the piano ...
	4	$\wedge\ \tau(e) = t']]$	...and that takes place at t'

This entry will reject VPs like *eat two apples*, because an interval that is the runtime of an event to which *eat two apples* applies has no subintervals which would again be the runtime of an event that falls under the denotation of *eat two apples*. In other words, *eat two apples* does not have the **subinterval property**. But VPs like *play the piano*, *eat apples* or *push a cart* do have the subinterval property, so they are not rejected.

Both entries are compatible with the facts in (5). Now we turn to a case where Krifka's entry fails: cumulative readings (Scha, 1981).

3.2 Landman: Cumulativity in the case of two QNPs

Here is a sentence with a cumulative reading:

(18) Three professors talked to four prospective graduate students.

The cumulative reading of (18) expresses that the total number of professors that talked to a prospective student is three and the total number of prospectives that were talked to by a professor is four. Note that this does **not** mean that each professor talks to all the prospective students. There could be a subevent in which professor 1 talks to student 1 and nobody else.

In a non-event-based framework (e.g. Scha, 1981), this can be represented as follows. We use sums to represent the meaning of the two noun phrases, and Link (1983)'s star operator to close predicates under sum: ${}^*P(x)$ is true iff P holds of every atomic part of x. Note that $P(x) \Rightarrow {}^*P(x)$. We use capital letters as a reminder whenever we are dealing with sums. We write "three-professors(X)" as a shorthand for " *professor$'(X) \wedge |X| = 3$".

	Non-event-based representation for (18):		
	1	$\exists X$ three-professors(X)	There is a sum X of 3 professors
(19)	2	$\wedge\ \exists Y$ four-prospectives(Y)	There is a sum Y of 4 prospectives
	3	$\wedge\ \forall x \in X\ \exists y \in Y$ talked-to$'(x, y)$	Every prof talked to a prospective
	4	$\wedge\ \forall y \in Y\ \exists x \in X$ talked-to$'(x, y)$	To every prospective, a prof talked

We follow Landman (2000) in representing cumulative readings in a way that makes explicit reference to events (contra what we have just seen), mainly for compatibility: the entries for *for*-adverbials we want to compare presuppose such a representation. We briefly describe Landman's representation of cumulativity.

We will state that individuals are participants in an event using thematic roles: agent(e) $= x$ means that x is the agent of e. We will use the star operator to generalize these roles: *agent(E) $= X$ means that every member of X is the agent of an event in the sum event E, and no nonmember of X is the agent of an event in E. In other words, the agents of the parts of E sum up exactly to X.

With this in place, the cumulative reading of (18) can be described as follows:

(20) **Representation for (18):**

1	$\exists X$ three-professors(X)	There is a sum X of three professors
2	$\wedge\ \exists Y$ four-prospectives(Y)	There is a sum Y of four prospectives
3	$\wedge\ \exists E\ ^*$talk-to$'(E)$	There is a sum E of talking events
4	$\wedge\ ^*$agent$(E) = X$	The agents of E sum up to X
5	$\wedge\ ^*$patient$(E) = Y$	The patients of E sum up to Y

Now consider Krifka's and Dowty/Moltmann's predictions for (21).

(21) Three professors talked to four prospective graduate students for an hour.

Intuitively, (21) means that at every relevant subinterval of an hour, "three professors talked to four prospective graduate students" is true, i.e. as before, the total number of talking professors is three and the total number of talked-to prospectives is four, and it is **not** necessary that at every subinterval, each professor talked to all the prospectives.

Krifka's entry, assuming we QR *four prospectives*, produces the following representation:

(22) **Krifka's representation for (21):**

1	$\exists X$ three-professors(X)	There is a sum X of three professors
2	$\wedge\ \exists Y$ four-prospectives(Y)	There is a sum Y of four prospectives
3	$\wedge\ \exists E\ ^*$talk-to$'(E)$	There is a sum E of talking events
4	$\wedge\ ^*$agent$(E) = X$	The agents of E's atomic parts sum up to X
5	$\wedge\ ^*$patient$(E) = Y$	The patients of E's atomic parts sum up to Y
6	$\wedge\ H'(E) = 1$	The duration of E is one hour
7	$\wedge\ \partial\exists e'[e' <_{H'} E]$	Presupp.: E has shorter subevents
8	$\wedge\ \forall e''[e'' \leq_{H'} E \rightarrow$	Each shorter subevent ...
9	*talk-to$'(e'')$	is a talking event
10	$\wedge\ ^*$agent$(e'') = X$	whose agents sum up to X
11	$\wedge\ ^*$patient$(e'') = Y]$	and whose patients sum up to Y

This is stronger than the cumulative reading. It requires that each professor talks to all the prospectives all the time. A subevent in which professor 1 talks to prospective 1 exclusively for a few minutes is not allowed. This is clearly too strong.

Again assuming we QR *four prospectives*, Dowty/Moltmann's entry produces the following – correct – representation:

(23)

Dowty/Moltmann representation for (21):

1	$\exists X$ three-professors(X)	There is a sum X of three professors
2	$\exists Y$ four-prospectives(Y)	There is a sum Y of four prospectives
3	$\wedge\ \exists t\ [H(t) = 1$	There is an interval t that lasts 1 hour
4	$\wedge \forall t'\ [t'\mathrm{P}t \rightarrow$	At each relevant subinterval t' ...
5	$\exists e.$	... there is an event ...
6	$\tau(e) = t'$	... which takes place at t' ...
7	$\wedge\ {}^*$talk-to$'(e)$	... and which is a talking event ...
8	$\wedge\ {}^*$agent$(E) = X$	... whose agents sum up to X ...
9	$\wedge\ {}^*$patient$(E) = Y$	... and whose patients sum up to Y.

Interim conclusion: *for*-adverbials distribute over subintervals, as predicted by Dowty/Moltmann, not subevents as predicted by Krifka.

4 A unified account of nominal distributivity

In this section, we provide a generalized account of distributivity in the cases of two and three quantifiers.

4.1 Landman: Distributivity in the case of two QNPs

Simple example of distributivity with two quantifiers:

(24) Three boys (each) invited four girls.

(Landman, 2000, ch. 6) derives both cumulative and distributive readings. All thematic roles start out on the verb and come with the star operator out of the box. Cumulative readings are derived by applying QNPs in situ. Distributive readings are derived by raising a QNP with a special operation called SQI. We can think of SQI as applying a distributive operator [dist$_{Landman}$] to a QNP and then raising it to give it wide scope above the VP and above existential closure over the event variable.

[dist$_{Landman}$] can be defined as follows:

(25) $[\![\text{[dist}_{Landman}]]\!]_{\langle\langle et,t\rangle,\langle et,t\rangle\rangle} = \lambda Q_{\langle et,t\rangle}.\lambda P_{et}.Q(\lambda y_e.\forall x\ [x \in AT(y) \rightarrow P(x)])$

(26)

Example: Result of applying $[\![[\text{dist}_{Landman}]]\!]$ to $[\![\text{three boys}]\!]$

1	λP_{et}.	Arg: the IP, abstracting over QNP trace
2	$\exists X_e$ three-boys(X)	There is a sum X of three boys
3	$\wedge\ \forall x\ [x \in AT(X) \rightarrow P(x)]$	To each of these boys, the IP applies

(27)

Example: Landman's representation for (24) using $[\text{dist}_{Landman}]$

1	$\exists X$. three-boys(X)	There is a sum X of three boys ...
2	$\wedge\ \forall x\ [x \in AT(X) \rightarrow$	... and for each boy (for each atom of X) ...
3	$\exists Y$. four-girls(Y)	... there is a sum Y of four girls ...
4	$\wedge\ \exists e\ [{}^*\text{invite}'(e)$	... and a sum of inviting events ...
5	$\wedge\ {}^*\text{agent}(e) = x$	... whose agent is x ...
6	$\wedge\ {}^*\text{theme}(e) = Y]]]]$	... and whose themes sum up to Y

In (27), there is only one event variable, e, and it's in the scope of the distributing universal, $\forall x$. So there is no variable that stands for the entire sum event. However, some adjuncts can modify this sum event:

(28) Unharmoniously, three tenors (each) sang a scale.

So the event variable introduced by the verb is in the scope of a distributing universal, there should be another one representing the sum event. We'll call it the *outer event*.

The next section shows that not only adjuncts like *unharmoniously* but also arguments can modify the outer event.

4.2 Schein: Distributivity in the case of three QNPs

Schein (1993) and Landman (2000) discuss sentences with three QNPs A, B, and C, where A and B stand in a cumulative relation and B distributes over C:

cumulative

(29) $[_A$ Three boys] gave $[_B$ six girls] $[_C$ two flowers (each)].

external arg

distributive

Intended reading: Three boys in total, six girls in total, two flowers per girl (i.e. twelve flowers in total).

Landman's SQI can't be generalized to this kind of sentence, because it doesn't allow the distributing quantifier (B) to enter in a cumulative relation with another quantifier (A). Landman (2000) already recognizes this (ch. 10).

More generally, sentences like (29) need to be represented using two event variables, as Schein (1993) argues:

Schein-style representation for (29):

(30)

1	$\exists X.$ three-boys(X)	There is a sum X of three boys
2	$\wedge\ \exists E.\ ^{*}$agent$(E) = X$	who is the sum agent of an event E
3	$\wedge\ \exists Y.$ six-girls(Y)	and there is a sum Y of six girls
4	$\wedge\ \forall y\ [y \in AT(Y) \rightarrow$	and for each of these girls the following holds:
5	$\exists e \leq E.$	[there is a sum subevent e of E
6	$[^{*}$give$'(e)$	that is a giving event
7	$\wedge\ ^{*}$recipient$(e) = y$	and has that girl as its recipient
8	$\wedge\ \exists Z$ two-flowers(Z)	and there is a sum Z of two flowers
9	$\wedge^{*}$theme$(e) = Z]]$	which is the sum theme of that subevent e]

The outer event variable (here E) is modified by the quantifier A and the inner variable (here e) is modified by B and C.

The important parallel to notice is that *three boys* in (29) is like *unharmoniously* in (28) in that both modify the outer event.

4.3 A proposal for how arguments and adjuncts combine with verbs

Kratzer (1994, 1996) tries to choose between these (and similar) representations for verbal denotations:

(31) $[\![\text{rent}]\!]$ (transitive) =

a. $\lambda y.\lambda x.\text{rent}'(x, y)$ (textbook answer)

b. $\lambda y.\lambda x.\lambda e.[\text{rent}'(e) \wedge \text{theme}(e) = x \wedge \text{agent}(e) = y]$ (event semantics)

c. $\lambda x.\lambda e.[\text{rent}'(e) \wedge \text{agent}(e) = x]$ (no one, really)

d. $\lambda y.\lambda e.[\text{rent}'(e) \wedge \text{theme}(e) = y]$ (Kratzer, 1996)

e. $\lambda e.\text{rent}'(e)$ **(this proposal)**

As she observes, in a representation like (30), the sum agent predicate modifies another event variable than the other event predicates – i.e. we have *give$'(e)$, *recipient(e) and *theme(e), but *agent(E) and not *agent(e). This is impossible under (31a-c), so (31d) and (31e) remain as options. Kratzer argues for (31d) because it captures asymmetries between internal and external arguments.

However, we can rule out (31d) as well, using an argument parallel to her own. The following sentence is analogous to (29), but this time it is the internal argument that is argument A, and therefore modifies the outer event variable:

cumulative

(32) [$_A$ Two treaties] were signed by [$_B$ six diplomats] with [$_C$ a personalized pen].[2]
internal arg

distributive

Intended reading: Two treaties in total, six diplomats in total, one pen per diplomat (i.e. six pens in total).

By Kratzer's logic, (31e) remains as the only option.

Interim conclusions:

- No reflection of theta roles and argument structure in verb meaning.
  - Except if verb meaning is a *set* of model-theoretic objects. Then some of them can be the theta roles. See the TAG implementation later on.
- No semantic differences between internal and external argument.
- No semantic differences between arguments and adjuncts.
- Need an abstract head or similar device to introduce the internal argument, similarly to little v for the external argument as claimed by Kratzer.

Sample lexical entries

Verbs:

(33) $[\![\text{rent}]\!] = \lambda e_v.\text{rent}'(e)$

Thematic heads:

(34) $[\![[\text{theme}]]\!]_{\langle e,\langle vt,vt\rangle\rangle} = \lambda x_e.\lambda f_{vt}.\lambda e_v.f(e) \wedge {}^*\text{theme}(e) = x$
Takes a sum individual x and a property of events f – supplied by a verbal projection – and intersects f with the property of having x as one's sum theme

Prepositions (like thematic heads but overt):[3]

[2]Judgment courtesy Aviad Eilam. For Josh Tauberer, it is better to say *Two treaties were signed with a personalized pen by six diplomats* (under the indended reading). Also, pragmatic pressures will usually make us prefer to realize *pen* as a dependent plural, see e.g. Joh (2008) (Penn dissertation, advisor: S. Malamud).

[3]Simplified treatment. Nested PPs require lifting the preposition or more complicated entries, see Pratt and Francez (2001); von Stechow (2002); Beaver and Condoravdi (2007).

(35) $[\![\text{in}_{locative}]\!]_{\langle e,\langle vt,vt\rangle\rangle} = \lambda x_e.\lambda f_{vt}.\lambda e_v.f(e) \wedge {}^*\text{loc}'(e) = x$
$[\![\text{at}_{temporal}]\!]_{\langle e,\langle vt,vt\rangle\rangle} = \lambda t_e.\lambda f_{vt}.\lambda e_v.f(e) \wedge {}^*\tau(e) = t$

Little v in its agent instantiation – we need other instantiations when the external argument is not an agent or when there is no external argument. (Like thematic heads, but specifier and complement are inverted):

(36) $[\![[_{v^0}\text{agent}]]\!]_{\langle vt,\langle e,vt\rangle\rangle} = \lambda f_{vt}.\lambda x_e.\lambda e_v.{}^*\text{agent}(e) = x \wedge f(e)$

4.4 Generalizing distributivity across two and three QNPs

The following operator successfully derives the representation in (30):

(37) $[\![[\text{sepdist}_{QNP}]]\!]_{\langle\langle e,\langle vt,vt\rangle\rangle,\langle\langle et,t\rangle,\langle vt,vt\rangle\rangle\rangle}$
$= \lambda H_{\langle e,\langle vt,vt\rangle\rangle}.\lambda Q_{\langle et,t\rangle}.\lambda f_{vt}.$
$\lambda e_v.Q(\lambda y_e.\forall x\ [x \in AT(y) \rightarrow \exists e'[e' \leq e \wedge H(x)(f)(e')]])$

[sepdist$_{QNP}$] takes a thematic role head H, a QNP Q, and a property of events f (usually supplied by a verb or verb phrase). It returns a property that is true of any sum e of events such that for every atomic part y of the individual x bound by the quantifier, there is a part of e that stands in the relation H to y.

As an example, here is the result of combining [sepdist$_{QNP}$] first with [recipient] and then with *six girls*:

(38) $[\![[\text{sepdist}_{QNP}]]\!]([\![[\text{recipient}]]\!])([\![\text{six girls}]\!])_{\langle vt,vt\rangle}$
$= \lambda f_{vt}.\lambda E_v.\exists X\ \text{six-girls}(X) \wedge \forall x\ [x \in AT(X) \rightarrow$
$\exists e'[e' \leq E \wedge f(e') \wedge {}^*\text{recipient}(e') = x]]$

This function takes any property f of events (a verb phrase, for example) and returns the property that is true of any event E for which there are six girls who each are the recipient of a subevent of E to which f applies. So it makes E accessible for modification, unlike [dist$_{Landman}$], repeated here from (25):

(39) $[\![[\text{dist}_{Landman}]]\!]_{\langle\langle et,t\rangle,\langle et,t\rangle\rangle}$
$= \lambda Q_{\langle et,t\rangle}.\lambda P_{et}.Q(\lambda y_e.\forall x\ [x \in AT(y) \rightarrow P(x)])$

We can use our operator instead of [dist$_{Landman}$] to derive distributivity in the case of two quantifiers, as in (40), shown here with the representation that [sepdist$_{QNP}$] generates:

(40) Six girls (each) got two flowers.
$\exists E\ \exists X[\text{six-girls}(X) \wedge \forall x\ [x \in AT(X) \rightarrow$
$\exists Y[\text{two-flowers}(Y) \wedge \exists e[{}^*\text{got}'(e)\ \wedge\ e \leq E$
$\wedge {}^*\text{recipient}(e) = x \wedge {}^*\text{theme}(e) = Y]]]]$

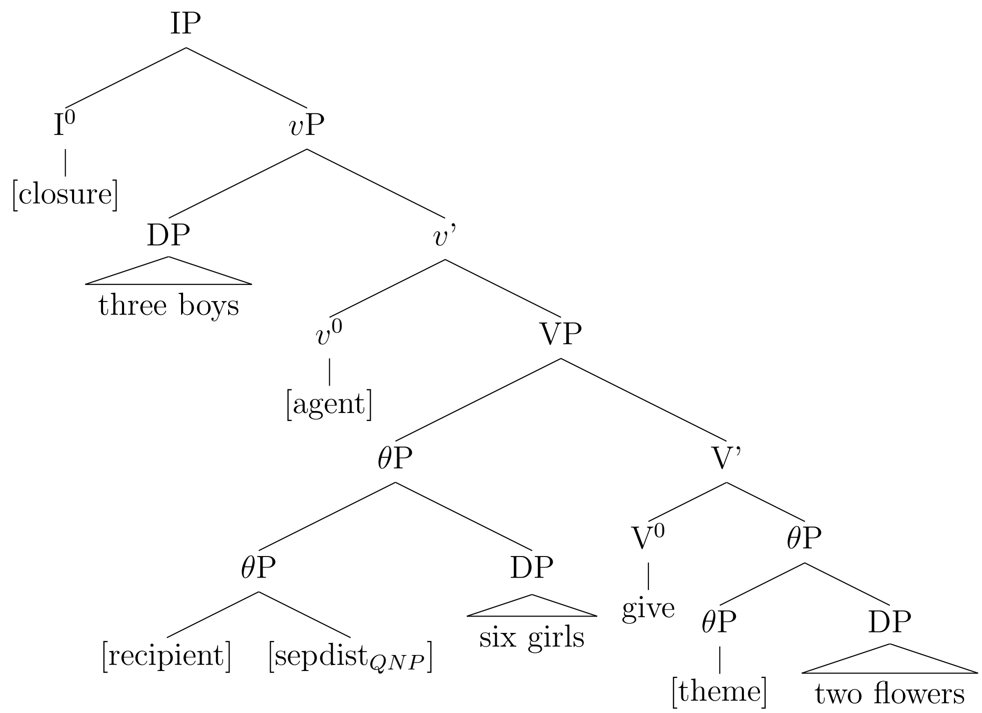
Since events are closed under sum, the statement $\exists E$ is vacuous. This means that (40) is equivalent to the representation that [dist$_{Landman}$] produces:

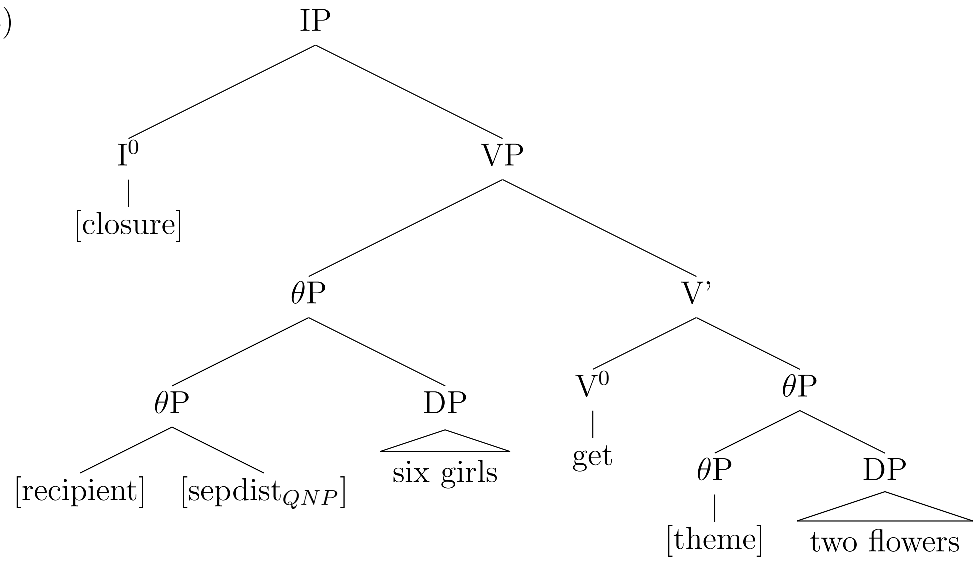
(41) $\exists X$[six-girls$(X) \wedge \forall x\ [x \in AT(X) \rightarrow$
$\exists Y$[two-flowers$(Y) \wedge \exists e[^*\text{got}'(e)\ \wedge\ e \leq E$
$\wedge^*\text{recipient}(e) = x \wedge {}^*\text{theme}(e) = Y]]]]$

The difference between [dist$_{Landman}$] and [sepdist$_{QNP}$] is that only the latter makes E accessible to further modification, e.g. by a QNP as in (29). E represents the whole event or situation.

Proposed LFs (see written proposal for interpretation):

(42)



(43) 

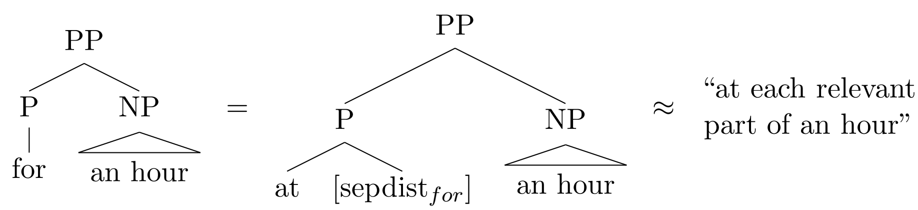
Interim conclusion: The distributivity operator [sepdist$_{QNP}$] generalizes over the case with two and the case with three QNPs. Unlike Landman's [dist$_{Landman}$], it makes the variable repesenting the whole event or situation accessible for modification higher up.

5 A unified account of nominal and adverbial distributivity

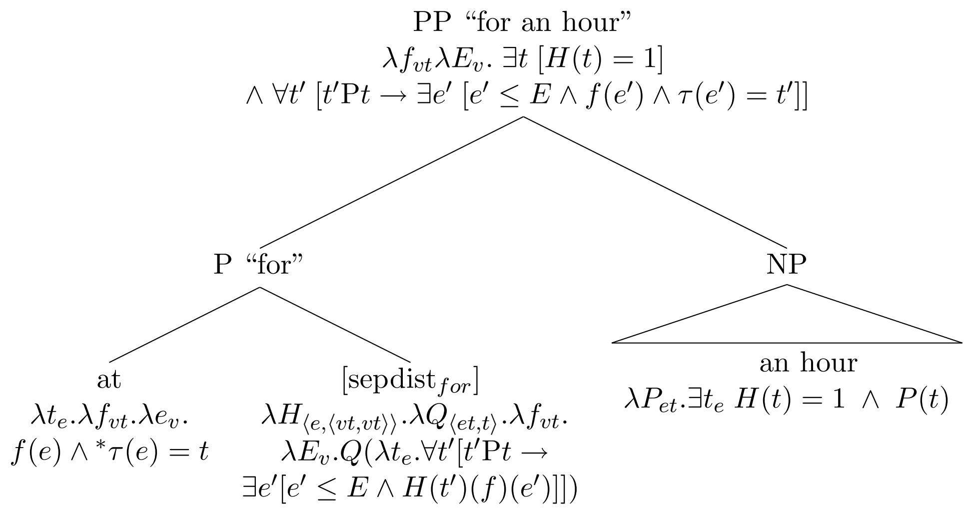
We now come to the centerpiece of this proposal. We show that there is a close connection between the generalized distributivity operator and the distributive part of *for*-adverbials.

5.1 Identifying the distributivity operator in *for*-adverbials

The durative preposition *for* can be decomposed into a thematic head corresponding to the preposition *at* and a distributivity operator [sepdist$_{for}$]:

(44) 

(45)



This is in fact not quite Moltmann's entry for *for an hour.* The differences are that we introduce an outer event E (this is independently needed) and we drop the subject argument (since it can modify the outer event).

5.2 Generalizing distributivity across QNPs and *for*-adverbials

Let's compare our entries for [sepdist$_{QNP}$] and [sepdist$_{for}$], each derived from independent motivations:

(46) $[\![\text{[sepdist}_{QNP}]]\!]$ (= 37)
$= \lambda H_{\langle e,\langle vt,vt\rangle\rangle}.\lambda Q_{\langle et,t\rangle}.\lambda f_{vt}.$
$\lambda e_v.Q(\lambda y_e.\forall x\ [x \in AT(y) \rightarrow \exists e'[e' \leq e \wedge H(x)(f)(e')]])$

(47) $[\![\text{[sepdist}_{for}]]\!]$ (= 45)
$= \lambda H_{\langle e,\langle vt,vt\rangle\rangle}.\lambda Q_{\langle et,t\rangle}.\lambda f_{vt}.$
$\lambda e_v.Q(\lambda t_e.\forall t'[t'\mathrm{P}t \rightarrow \exists e'[e' \leq e \wedge H(t')(f)(e')]])$

Since the use of letters x, y and t, t' is only for clarity of exposition, the only difference is the nature of the relation P. In one case, it is contextually supplied, in the other case, it is instantiated as $\lambda y \lambda x.y \in AT(x)$, or shorter, *is-atom-of*.

But we know that *is-atom-of* is not always correct either! Remember example (9), repeated here:

Scenario: Last year, Groenendijk and Stokhof got a joint Spinoza Prize for their dissertation, and Johan van Benthem got a Spinoza Prize for his life's work.

(48) Last year, three Dutch professors received a Spinoza prize in linguistics.

Incorrect paraphrase: Three Dutch professors are such that each of them got a Spinoza prize.
Better paraphrase: A sum total of Dutch professors are such that each of its **relevant subparts** got a Spinoza prize. (Schwarzschild, 1991, 1996)

It seems that the only relevant constraint on the subparts is that they form a *partition* of the DP. The following generalized operator expresses this idea:

(49) $[\![\text{sepdist}]\!]_{\langle\langle e,\langle vt,vt\rangle\rangle,\langle\langle et,t\rangle,\langle vt,vt\rangle\rangle\rangle}$ (official entry)
$= \lambda H_{\langle e,\langle vt,vt\rangle\rangle}.\lambda Q_{\langle et,t\rangle}.\lambda f_{vt}.$
$\lambda e_v.Q(\lambda y_e.\forall x\, [x \in \text{Part}_i(y) \rightarrow \exists e'[e' \leq e \wedge H(x)(f)(e')]])$

Here, Part_i is a contextually given partition. In the dissertation, I will try to derive it from speaker/hearer intentions using formal pragmatic methods – decision theory as in Malamud (2006) (Penn dissertation, advisor: M. Romero), or its close relative, game theory.

6 The syntax-semantics interface: Application to TAG

The following TAG fragment generates distributive and cumulative readings of *Three boys invited four girls* as well as three-quantifier sentences and sentences with *for an hour*.

6.1 Two-quantifier sentences

We will generate the following structures:

(50) a. Surface scope distributive reading
Each boy invites a sum total of four girls
⟦closure⟧(⟦sepdist⟧(⟦agent⟧)(⟦three-boys⟧) (⟦theme⟧(⟦four-girls⟧)(⟦invited⟧)))

b. Inverse scope distributive reading
Each girl is invited by a sum total of three boys
⟦closure⟧(⟦sepdist⟧(⟦theme⟧)(⟦four-girls⟧) (⟦agent⟧(⟦three-boys⟧)(⟦invited⟧)))

c. Cumulative reading
A sum total of three boys invite a sum total of four girls
⟦closure⟧(⟦agent⟧(⟦three-boys⟧) (⟦theme⟧(⟦four-girls⟧)(⟦invited⟧)))

Fig. 1 shows a sample TAG that derives the sentence *Three boys invited four girls to two parties*, along with a derived tree and a derivation tree for this sentence. Fig. 2 and 3 show how to associate the elementary trees with semantics. They generate a scopally underspecified representation as an intermediate step that compactly encodes scope ambiguities (Bos, 1995; Althaus et al., 2003).

6.2 A very simple constraint system for underspecified semantics

Every lexical item is associated with one or more labeled λ expressions (Fig. 2). A *scope constraint* $l_1 > l_2$ indicates that the λ expression labeled l_1 has to be applied to (an expression which has to be applied to...) the one labeled l_2. These applications have to be well-typed. We write $l_1 > l_2 > \ldots > l_n$ to express the conjunction of constraints $l_1 > l_2 \wedge l_2 > l_3 \wedge \ldots \wedge l_{n-1} > l_n$.

An expression that carries an optional label may or may not occur. Any scope constraints that mention an optional label only need to be observed in derivations in which an expression that carries this label is present.

The underspecified representation in Fig. 2, lower right, generates the three readings in (50). We have two labels both with value $[\![\text{sepdist}]\!]$ because each QNP may come with its own [sepdist] operator.

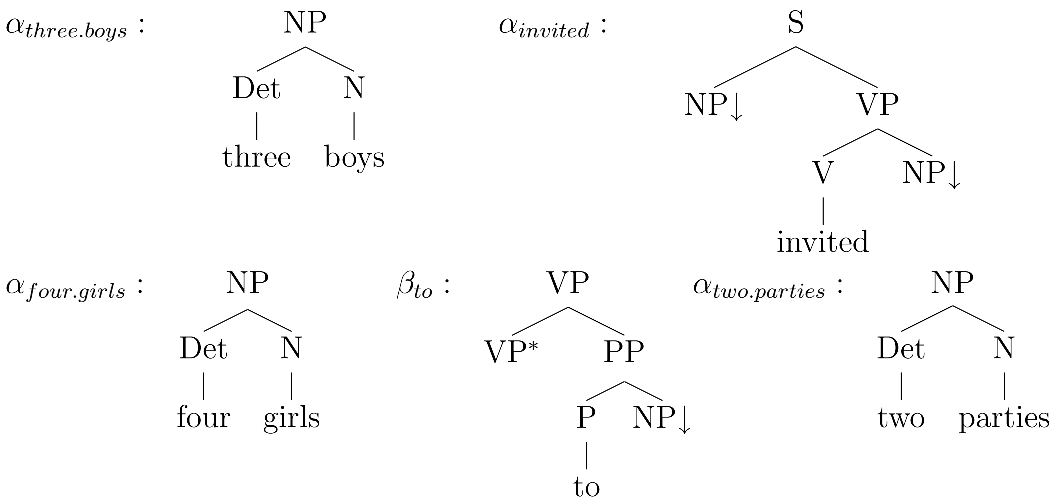
6.3 Discussion

This fragment is a sketch of the first ever event-based semantics for Tree-adjoining Grammar (TAG), which opens the door to a TAG semantic treatment of plurals, events, and quantification. It also shows a way to include thematic roles in verbal denotations as long as they are separate model-theoretic objects. Since our semantics makes no difference between arguments and adjuncts, an application to LTAG-spinal is in reach, a NLP-friendly variant of TAG that also does not make this difference (Shen, Champollion and Joshi 2008).

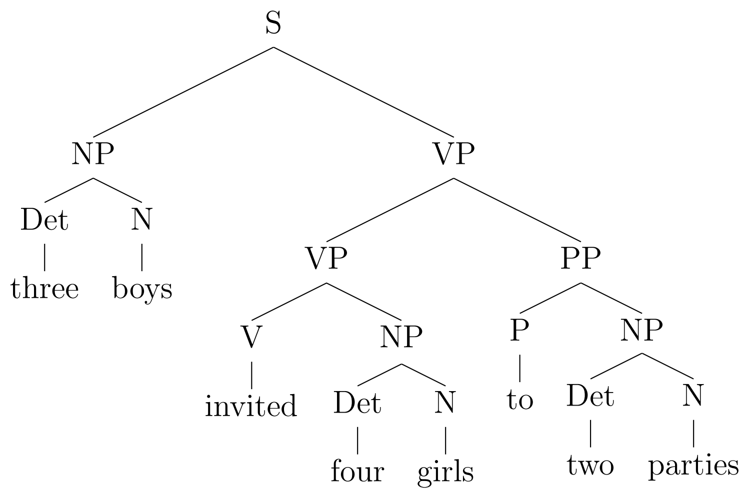
7 Conclusion

This proposal provides evidence for the following hypotheses (from Section 1):

Elementary trees



Derived tree



Derivation tree

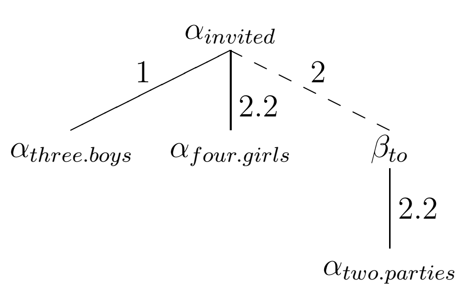
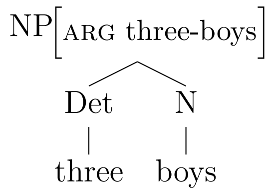
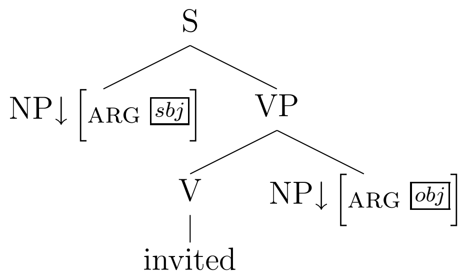
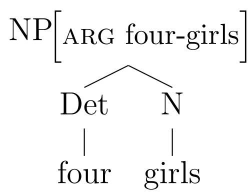
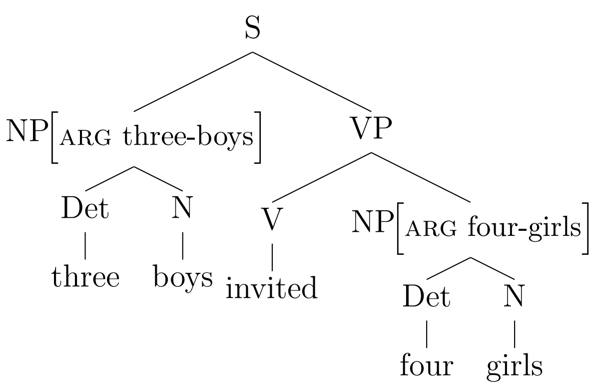


Figure 1: A TAG that derives the sentence *Three boys invited four girls to two parties.*

<table>
<tr><th>Entry</th><th>Syntax</th><th>Semantics</th></tr>
<tr><td>$\alpha_{three.boys}$</td><td>
</td><td>three-boys: ⟦three-boys⟧</td></tr>
<tr><td>$\alpha_{invited}$</td><td>
</td><td>invited : ⟦invited⟧
ag : ⟦agent⟧
th : ⟦theme⟧
closure : ⟦closure⟧
(sepdist-ag) : ⟦sepdist⟧
(sepdist-th) : ⟦sepdist⟧
closure > (sepdist-ag) > ag
> $\boxed{sbj}$ > invited
closure > (sepdist-th) > th
> $\boxed{obj}$ > invited</td></tr>
<tr><td>$\alpha_{four.girls}$</td><td>
</td><td>four-girls: ⟦four-girls⟧</td></tr>
</table>



Label	**Denotation**
three-boys :	⟦three-boys⟧
four-girls :	⟦four-girls⟧
invited :	⟦invited⟧
ag :	⟦agent⟧
th :	⟦theme⟧
closure :	⟦closure⟧
sepdist-ag (optional):	⟦sepdist⟧
sepdist-th (optional):	⟦sepdist⟧
closure > (sepdist-ag) > ag > three-boys > invited	
closure > (sepdist-th) > th > four-girls > invited	

Figure 2: On top, the same TAG as in Fig. 1 (except for the PP *to two parties*), augmented with a semantic representation. Below, a derived tree for *Three boys invited four girls*, along with the underspecified semantic representation generated by the entries above.

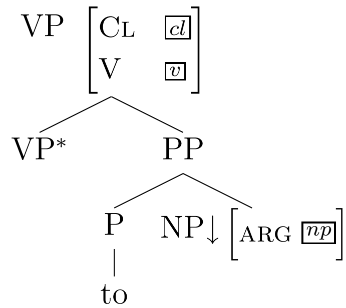
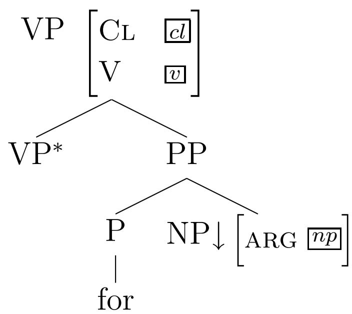
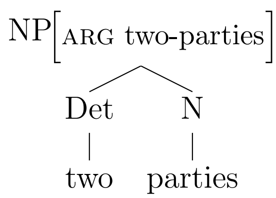
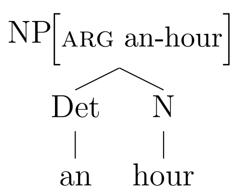
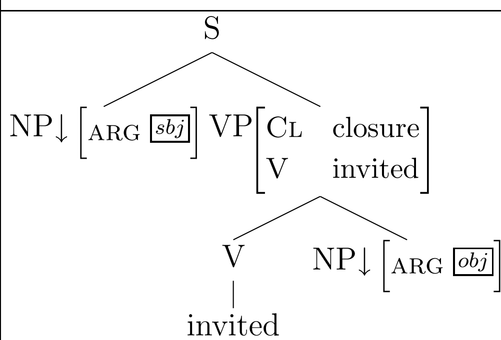
Entry	Syntax	Semantics
β_{to}		loc : ⟦loc⟧ (sepdist-loc) : ⟦sepdist⟧ cl > (sepdist-loc) > loc > np > v
β_{for}		time : ⟦time⟧ sepdist-for : ⟦sepdist⟧ cl > sepdist-for > time > np > v
$\alpha_{two.parties}$		two-parties : ⟦two-parties⟧
$\alpha_{an.hour}$		an-hour : ⟦an-hour⟧
$\alpha_{invited}$ (revised)		*as in Fig. 2*

Figure 3: TAG treatments for the PPs *to two parties* and *for an hour*.

Hypothesis 1: As far as verbal denotations go, there is no difference between internal arguments, external arguments, and adjuncts, contra Kratzer (1996). Arguments and adjuncts combine with the verb via thematic roles. Any observable differences must be due to syntax or other factors.
Hypothesis 2: There is only one kind of distributivity. The properties of distributivity can be captured by postulating a single operator.
Hypothesis 3: *for*-adverbials contain the distributivity operator, which distributes the predicate over subintervals, not subevents, contra Krifka (1998).

In terms of methodology, the proposal lays out a unified mereological framework for the treatment of verb-argument interactions, especially cumulative and distributive readings of two or more quantifiers and aspectual phenomena. It expands and generalizes previous frameworks by Krifka (1998) and Landman (2000).

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