A Theory of Non-constituent Coordination based on Finite-State Rules

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Introduction

Kaplan and Maxwell (1988) presented a theory of constituent coordination for LFG. Within the multilevel architecture of LFG (Bresnan 1982, Kaplan 1987), this analysis handled an example such as (1a) by a combination of a simple phrase structure rule for coordination such as (1b) to handle the c-structure (surface phrase structure), and a set representation of coordination at the level of f-structure (grammatical relations structure) as in (1c). The implementation of sets in the theory of LFG meant that the information about the subject, *Bill* was automatically distributed over the f-structures of both conjuncts, which gave a generally satisfactory theory of the distribution of information in coordinations, including the requirement for parallelism in the subcategorization of distributed predicates and an explanation of the well-known constraints on the interaction of coordination and long-distance dependencies.[1]

(1) a. Bill ate rice and recited a haiku.

b. VP → VP and VP

c.
$$\left\{ \begin{array}{c} \begin{bmatrix} \text{SUBJ} & \begin{bmatrix} \text{PRED} & \text{`Bill'} \end{bmatrix} \\ \text{PRED} & \text{`eat}\langle \text{—}, \text{—} \rangle\text{'} \\ \text{OBJ} & \begin{bmatrix} \text{PRED} & \text{`rice'} \end{bmatrix} \end{bmatrix} \\ \begin{bmatrix} \text{SUBJ} & \text{—} \\ \text{PRED} & \text{`recite}\langle \text{—}, \text{—} \rangle\text{'} \\ \text{OBJ} & \begin{bmatrix} \text{PRED} & \text{`haiku'} \end{bmatrix} \end{bmatrix} \end{array} \right\}$$

However, in common with other generative theories of the period, Kaplan and Maxwell (1988) dealt only with such cases of constituent coordination, ignoring the grab-bag of other cases of coordination commonly negatively classified as non-constituent coordination, such as 'conjunction reduction' (2a), Right-Node Raising (2b), Gapping (2c), Ellipsis (2d), and non-symmetric coordination (2e).

(2) a. Bill gave the girls spades and the boys recorders.

b. Bill likes, and Joe is thought to like cigars from Cuba.

c. Bill gave a rhino to Fred, and Sue a camera to Marjorie.

d. Bill likes big cars, and Sally does too.

e. Bill went and took the test.

This is unfortunate, since, as Milward (1994) observes, this distinction cannot be justified by grammaticality judgments alone. While some non-constituent coordinations seem forced or bookish, others are perfectly natural, especially many cases of VP 'conjunction reduction' such as (2a). Other subspecies from the above list are probably best treated separately. For example, Dalrymple et al. (1992) argue that ellipsis is best handled using higher-order unification at a semantic level, rather than through any form of syntactic (re)construction, and we assume a separate treatment is also required for gapping. Neither of these constructions requires the kind of syntactic parallelism observed in other cases of coordination (consider examples such as *A bandicoot escaped today and more will tomorrow* (Blevins 1994:19) where there is a mismatch in verbal form, or *A lot of this material can be presented in a fairly informal and accessible fashion, and often I do* (Dalrymple et al. (1992) citing text from Chomsky (1982:41)) where the first

[1]We are indebted to Milward (1994) for provoking and providing a starting point for this renewed research on coordination. Many of these ideas were discussed at various meetings and in email discussions and we thank the many participants: Caroline Brun, Max Copperman, Mary Dalrymple, Marc Dymetman, John Fry, Ron Kaplan, Lauri Karttunen, Martin Kay, Paula Newman, María-Eugenia Niño, Frédérique Segond, and Annie Zaenen. We are also grateful to Jim Blevins and Mark Johnson for comments.

passive clause does not provide a source for the VP-Ellipsis in the second clause. Similarly, non-symmetrical coordinations deviate systematically from the behaviour of other coordinations and are probably best viewed as a limited form of verb serialization in English (such sentences differ in that the conjuncts cannot be reversed while preserving meaning and in being exceptions to the Coordinate Structure Constraint (e.g., *Who did Bill go and see?*); see e.g., Pullum (1990)). We continue to set them aside. But following Jackendoff (1972), Blevins (1994), and the phrase structure grammar tradition more generally, we believe it is desirable that a syntactic theory of coordination should extend from constituent coordination to cases of 'conjunction reduction' and Right-Node Raising, and in this paper we outline such an extension to LFG, which allows new forms of c-structure licensing in the presence of coordinations, together with a mechanism to generate the correct f-structure forms.

Desiderata

We begin from the traditional idea that there should be a relationship between being able to say something of the form (3) and being able to say (4a) and (4b).[2]

(3) A [X and Y] B

(4) a. A X B

b. A Y B

It has been widely noted that the forwards implication does not hold (for what we take to be essentially semantic reasons), because you cannot uncoordinate sentences like:

(5) a. John and Mary are alike.

b. The man who buys and the woman who sells rattlesnakes meet in the bar on Wednesdays.

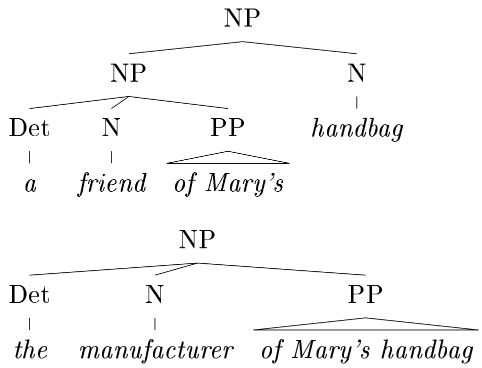
The backwards implication is uncontroversial with standard notions of constituency, but, as Milward (1994) notes, it actually becomes false when combined with a complete calculus of rules of use and proof, such as the Lambek calculus. For instance, one cannot say (6) (excluding the semantically dubious readings where handbags have friends or Mary can be maufactured), despite both the sentences in (7) being impeccable, because the structures of the NPs involved are different as shown in (8). Coordination is impossible when it would demand giving different analyses to material shared across conjuncts.

(6) *I found [a friend of] and [the manufacturer of] Mary's handbag.

(7) a. I found a friend of Mary's handbag.

b. I found the manufacturer of Mary's handbag.

(8) a. b.



However, the Lambek calculus overgenerates in cases like this because it allows us to form derivations where shared material gets different syntactic analyses with respect to each conjunct. For each conjunct, we can hypothesize the words of the shared material, and combine them differently in a derivation with the words of each conjunct. The hypotheses can then be discharged leaving two elements of identical category that can be conjoined using the standard polymorphic definition of *and* as a functor of type X\X/X. This unit then combines with the shared material, but the shared material is given a different structural and semantic analysis with respect to each conjunct.

Thus, while Categorial Grammar (CG) has had considerable success in dealing with problems of coordination, we observe a systematic overgeneration. It indicates that a theory of coordination must involve a greater degree of structural identity than is expressed simply by a CG-style category label. Such a result seems fundamentally antithetical to Categorial Grammar.

On the other hand, the requirement of categorial identity for coordination in CG also tends to cause undergeneration in cases like those in (9) where the constituent or constituents that are being coordinated differ in number or type, and hence coordination should not be permitted. While solutions to some of these cases have been proposed within CG, it is not clear that these proposals adequately capture the main intuition as to why these examples are good. That intuition is that the sentences in (9) are good because the

[2]Where A, B, X, and Y are taken as a sequence of words. Many theories have additionally restricted X and Y to be a (non-empty) constituent of some sort. For instance, Chomsky (1957:35) suggests the backwards implication holds in this case.

conjuncts are valid completions of the VP introduced by the verbs.

(9) a. Bill is nervous and a heavy smoker.

b. You can call me directly or after 3pm through my secretary.

c. Sue put a lamp on the table, and on the ledge a large antique punchbowl.

The basic idea

Our desideratum is therefore to provide an account of coordination within LFG which provides an appropriate degree of structure preservation – neither too much nor too little. The method will be to allow the coordination of partial expansions of c-structure rules. That is, rather than a coordination only licensing rules like (10a), it will also license the conjunction of fragments of the right-hand side of a rule. So if VP has the expansion in (10b), we want to license such overall expansions as the one in (10c).

(10) a. VP → VP and VP

b. VP → V (NP) (NP) PP*

c. VP →V [[NP PP] and [NP PP]] PP

In the theory underlying the LFG formalism, the right hand sides of phrase structure rules are regular languages, which can be represented as finite state automata (FSA). The first step of the new approach is to allow constituents to stop partway through a c-structure rule, in a particular state of the FSA, and then for the rest of the rule (i.e., the transitions to a final state of the network) to be completed later, as a coordination. Thus VP-x stops at a certain state in the expansion of the VP rule, and x-VP starts at this same point. This stopping point can be thought of as a point indicated by the placement of the dot (.) in chart-parsing. Importantly, since the FSA is deterministic, there will be a unique such state for any initial partial expansion of a rule.[3]

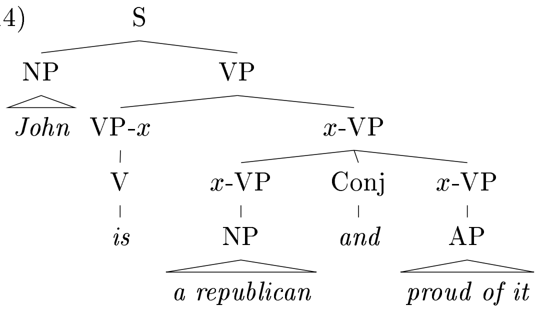
We are able to maintain the simple and classic rule for coordination that only identical things are allowed to coordinate, but now we allow the coordination of partial constituents, that is FSA segments stretching from one state to another, like x-VP and VP-x, as well. That is, we license rules of the form shown in (11) (where we omit the complications needed for conjoining several conjuncts, having pre-conjuncts like *both*, etc.).

[3]Even in the case when there is an ambiguity in the assignment of functional annotations to nodes, the FSA can be made deterministic by disjoining the functional annotations.

(11) XP → XP-x [x-XP-y Conj x-XP-y] y-XP

Here x-XP-y represents the part of the XP FSA from state x to state y. This allows the expansion of the right hand side of a rule to be divided into (possibly empty) parts before and after the coordination, and a central part that is coordinated. As (12) shows, this gives us an immediate account of the simplest cases of non-constituent coordination.

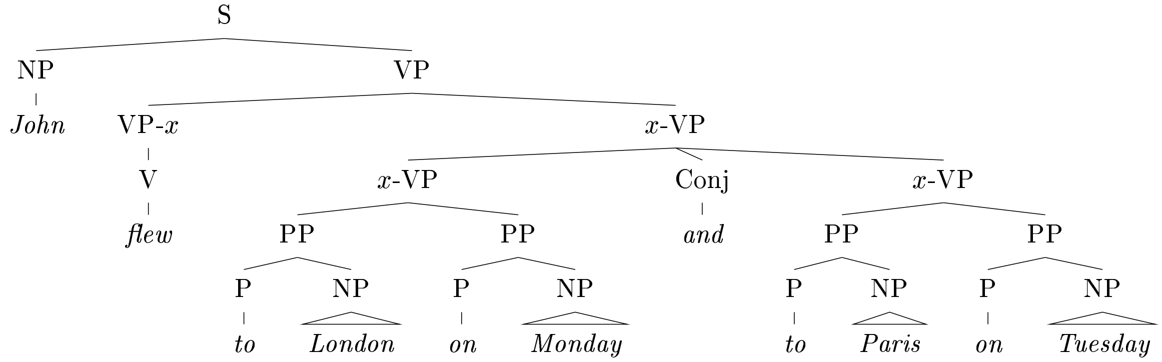
Because we are allowing the coordination of portions of phrase structure rules, we do not require the material in each conjunct to be of the same category or sequence of categories. Both conjuncts need merely be instantiations of the traversal of an FSA from a state s to a state e. Thus an example like (9b) where the number of elements in different constituents varies is not problematic, as shown in (13) (we have drawn the tree with adverbial phrases in the VP, but the analysis does not depend on this and would continue to work if any or all of the adverbial phrases were placed at the S level). Compared to Categorial accounts, in such cases we are moving the coordination up a level, in a similar way to the analysis of Blevins (1994). As another example, (14) shows how for *John is a republican and proud of it*, we are coordinating partial VPs rather than attempting to coordinate an NP and an AP. The result is that it is natural on our account that such examples should be admitted, whereas other accounts have had to fight to gain coverage of examples such as those in (9).

(14)


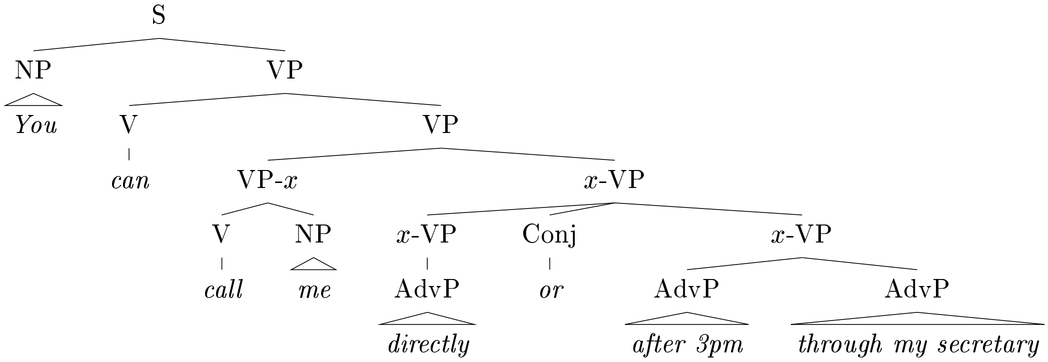
The examples that we have considered so far involve coordination only of right hand tails. But the same method can be used for medial coordinations if we allow coordination of parts of the expansion of the righthand side of a rule that are incomplete on both sides. Effectively we are maintaining the same idea of there being shared parts of the sentence and then separate parts for each conjunct of each conjunction. An example is shown in (15).

However, something slightly more complicated is needed to handle an example such as (16), since the conjuncts both complete an embedded PP and finish a VP above it.

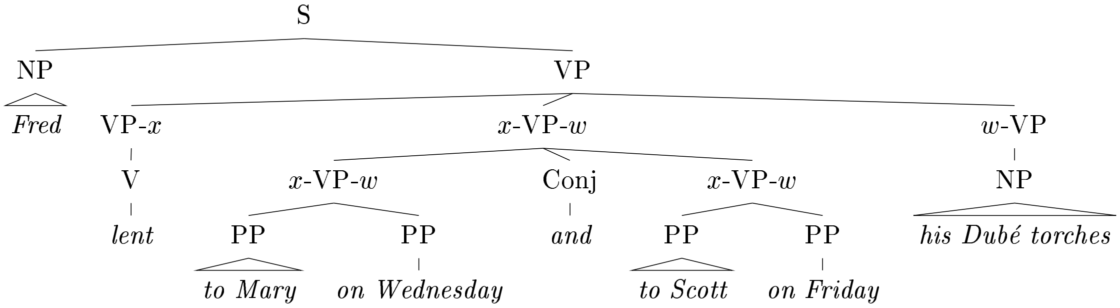
(12)


S
NP VP
John VP-x x-VP
V x-VP Conj x-VP
flew PP PP and PP PP
P NP P NP P NP P NP
to London on Monday to Paris on Tuesday

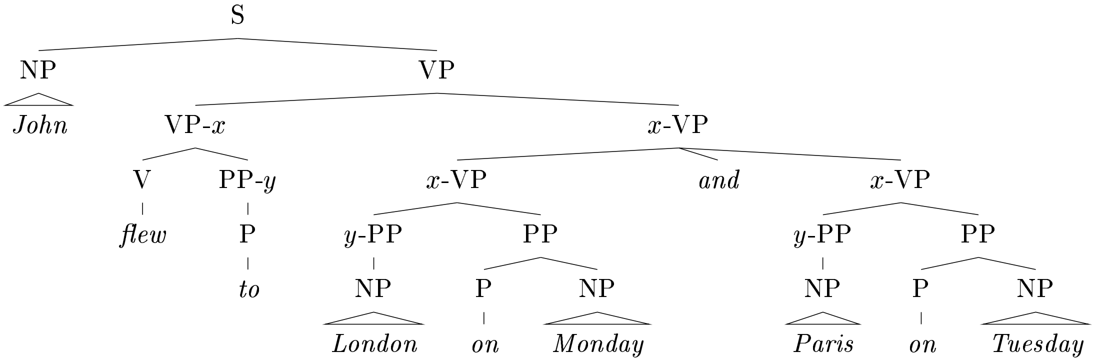
(13)


S
NP VP
You V VP
can VP-x x-VP
V NP x-VP Conj x-VP
call me AdvP or AdvP AdvP
directly after 3pm through my secretary

(15)


S
NP VP
Fred VP-x x-VP-w w-VP
V x-VP-w Conj x-VP-w NP
lent PP PP and PP PP his Dubé torches
to Mary on Wednesday to Scott on Friday

(17)


S
NP VP
John VP-x x-VP
V PP-y x-VP and x-VP
flew P y-PP PP y-PP PP
to NP P NP NP P NP
London on Monday Paris on Tuesday

(16) John flew to London on Monday and Paris on Tuesday

We can generate this by allowing for a stack of partially completed constituents with the requirement of well-formedness being that we can 'zip' together the multiple unfinished phrases with their continuations. Observe how this is true of the coordinated structure in (17): both of the conjuncts provide a valid completion for the unfinished PP and VP rules.[4]

When only a single rule involves partial constituents, it is straightforward that the parts go together to provide a complete constituent. When there are multiple incomplete rule expansions, we say that coordination is only possible when the stack of states (that represents partially completed rules) on the left of one partial constituent matches the stack of states on the right of the other and vice versa. Completed rules in between the partially completed rules are not placed on the stack of incomplete constituents, and so are ignored. In our pictures, we just draw the incomplete constituents in situ, but we imagine that, implementationally, these incomplete constituents would be passed up giving a stack of needed continuation states at the left and right margin of a phrase. The condition on well-formed coordinations is then to require matching as in (18), where $\mathbf{s}_i$ is a stack of inherited continuation states.

(18) XP $\rightarrow$ XP-$\mathbf{s}_1$ [$\mathbf{s}_1$-XP-$\mathbf{s}_2$ Conj $\mathbf{s}_1$-XP-$\mathbf{s}_2$] $\mathbf{s}_2$-XP

By using a rule like this, partial categories are only introduced in the context of a coordination, which explains why they do not count as normal constituents that can be topicalized or postposed, etc.

Maintenance of a stack of incomplete FSA in the parsing process also suggests an obvious source of performance effects. For example, if the temporal expressions in (19) were construed with the higher verb *wanted*, then this would require a stack of three incomplete FSA, as shown in (20). It is perhaps for this reason that such a reading is difficult (if not impossible) to get. There does not seem to be a similarly natural measure of complexity of coordination in Categorial approaches.

(19) John wanted to fly to London on an Airbus last week and Paris on a Boeing today.

[4] Of course, the VP FSA that we write here as VP-x is already in a final state (the one after the PP is completed). But the VP rule allows for this state to be followed by further PPs which leave the network in another final state.

The demand for phrase structure zipping between the shared material and each conjunct prohibits some of the cases of overgeneration that were seen in CG. For instance, we cannot form (21), as (22) attempts to indicate. This sentence is bad because you cannot coordinate the two partial NPs because they have different stacks of states on their right (the first has two states, the second just one).

(21) *I found [a friend of] and [the manufacturer of] Mary's handbag.

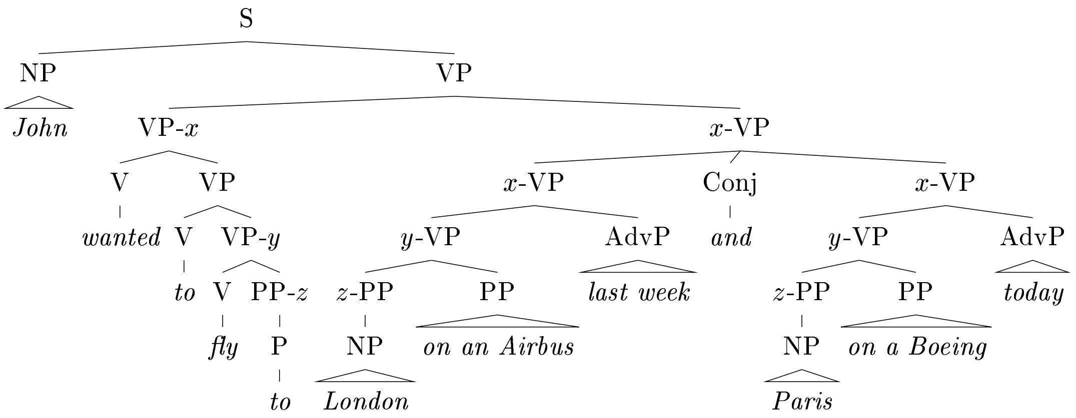
The approach just outlined extends a phrasal coordination analysis to a range of problematic constructions by allowing coordinations that involve units that are partial constituents, but nevertheless objects of a determinate, elsewhere appearing, type. While licensing partial constituents in the context of coordination, this approach does not claim that all coordinated elements are first class constituents in the manner of Categorial Grammar. This seems the right result given that the fragments that we are dealing with cannot be extracted, deleted or focused as regular constituents usually can (Blevins 1994). We have not yet discussed the f-structure representation of coordination and constraints coming from the f-structure, but we will postpone that until after some comparative remarks. We conclude this section with a final complicated example, employing all the techniques of this section, and showing the treatment of a complex coordination where the two conjuncts are of different sizes: see (23).

Comparison with other theories

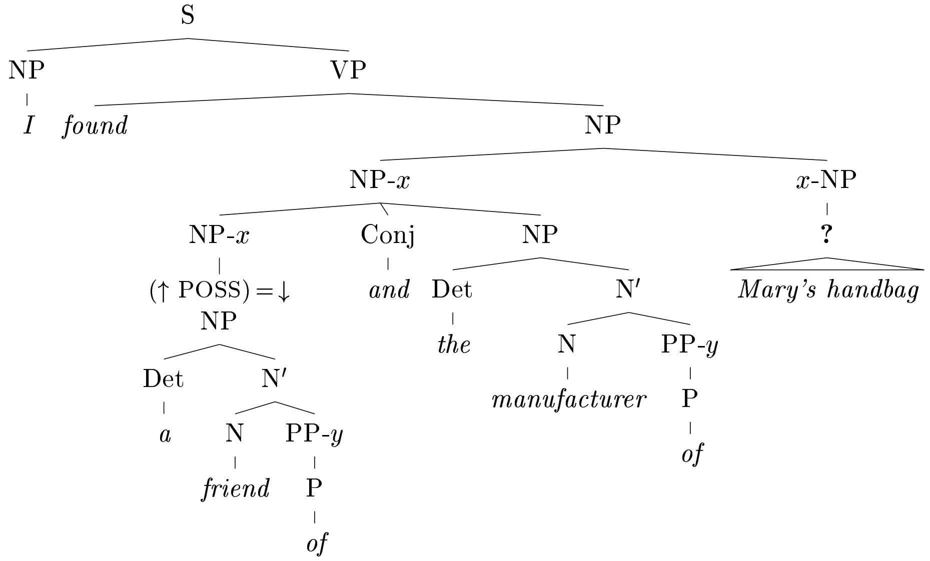
Within (computational) linguistics, treatments of coordination have generally involved either enriching the linguistic representation to include conjunctive structures or else adapting the parsing strategy to handle conjunction. Woods' (1973) SYSCONJ is an early and famous example of a system that used a special parsing strategy for coordination, and a variant of this strategy is also advocated by Milward (1994). On the representational side, in recent years there have been various proposals to handle non-constituent coordination within a variety of other frameworks, while, unlike Categorial Grammar, still maintaining conventional notions of phrase structure (Blevins 1994, Moltmann 1992, Sarkar and Joshi 1996).

While proposals go under very different names and may look notationally different, using ideas ranging from GB to lexicalized TAGs, we take it that the core intuition underlying many methods is the same. Indeed, there is not even a clear divide between the representational and processing

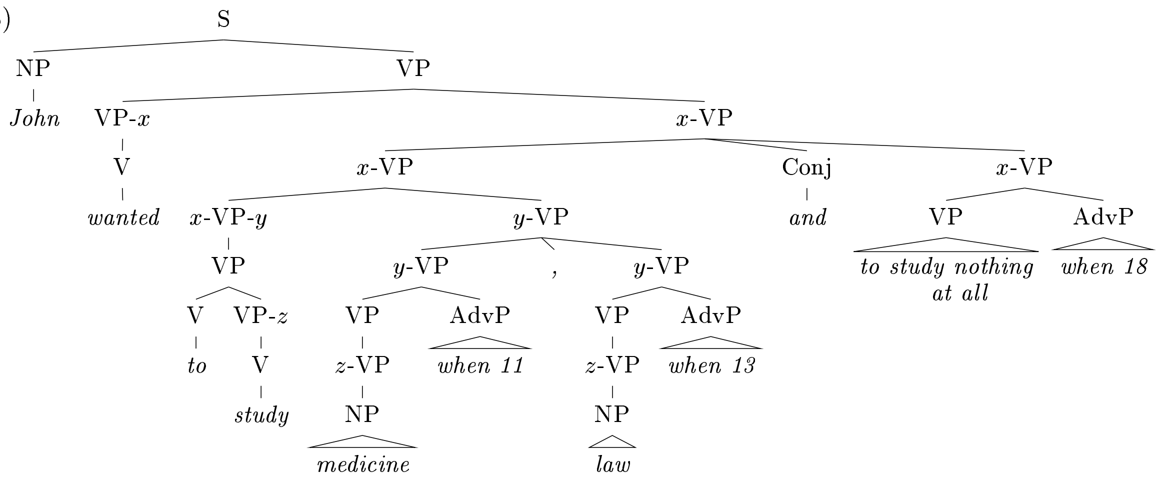
(20)


S
NP
VP
John
VP-x
x-VP
V
VP
x-VP
Conj
x-VP
wanted
V
VP-y
y-VP
AdvP
and
y-VP
AdvP
to
V
PP-z
z-PP
PP
last week
z-PP
PP
today
fly
P
NP
on an Airbus
NP
on a Boeing
to
London
Paris

(22)


S
NP
VP
I
found
NP
NP-x
x-NP
NP-x
Conj
NP
?
(↑ POSS) = ↓
NP
and
Det
N′
Mary's handbag
Det
N′
the
N
PP-y
a
N
PP-y
manufacturer
P
friend
P
of
of

(23)


S
NP
VP
John
VP-x
x-VP
V
x-VP
Conj
x-VP
wanted
x-VP-y
y-VP
and
VP
AdvP
VP
y-VP
,
y-VP
to study nothing
at all
when 18
V
VP-z
VP
AdvP
VP
AdvP
to
V
z-VP
when 11
z-VP
when 13
study
NP
NP
medicine
law

strategy techniques since a particular processing strategy can be used to enforce certain constraints that could alternatively be thought of as part of the grammatical representation. This duality can be seen clearly in the above LFG proposal where the states of the FSA can be thought of either as points reached during processing or as part of the representation of rules. Thus we both have the notion of "state" that Milward (1994) turns to (without having to postulate it in an otherwise unmotivated manner), and a declarative representation of conjunction.

The intuition behind all *shared structure* methods (as Milward (1994) names them) is that we can think of any sentence as consisting of shared parts and then pieces that belong to one conjunct, as in (24).

(24)
	Mary a book	
John gave	*and*	by Chomsky
	Peter a paper	

A sentence such as the one in (24) will be good providing the common parts and each conjunct yield a parse in which the syntactic structure assigned to the common parts is the same in each case. This intuition is perhaps most clearly seen in '3-D' or 'multidimensional' accounts of coordination (Goodall 1987, Moltmann 1992). Observe that both of the conjuncts in (24) can be seen as giving the middle portion of a VP expansion in different 'dimensions'. In (25) elements in the shared plane are shown with solid lines, while different dashes are used for the separate planes on which each conjunct appears. Note now that the LFG proposal for handling non-constituent coordination at c-structure is also a mechanism to allow some part of the finite state network expansion of a node to occur twice with an appropriate conjunction between the two parts, while the rest of the expansion appears only once. Whereas 3-D accounts attribute the possibility of sharing to the alignment of conjuncts on different planes, our analysis relies instead on having linearly strung out partial constituents. In general, we believe that there are quite strong similarities between our analysis and the other recent shared structure theories mentioned above: they represent a new breed of theories which allow non-constituent coordination by effectively moving coordinations up a level while maintaining classical notions of constituency (unlike Categorial Grammar).

This does not mean, however, that all methods incorporating this intuition give identical results. The outcome depends in part on various aspects of the representations used by the syntactic theory and the semantic representations that it in turn generates. Thus, for example, the SYSCONJ proposal has been faulted for being unable to assign a semantics to sentences like those in (5). Similarly, Milward (1994) faults 3-D accounts for being unable to account for examples where there are a different number of phrases in each conjunct, such as (9b) or (26).

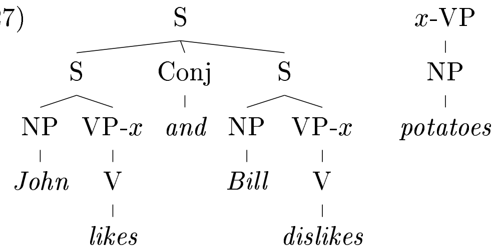
(26) We can meet [at the office] or [in London outside the theatre].

But this problem arises only if adjunct phrases are represented as (Chomsky-)adjoined phrases in the phrase structure. If we instead adopt a flatter conception of phrase structure, more in the tradition of dependency grammar, which makes adjuncts daughters of the phrase (while distinguishing adjuncts from governable grammatical functions at f-structure) then, as has already been shown, such examples are not problematic for our LFG proposal, just as they do not pose problems for Milward.

Right Node Raising

What we have presented so far can already handle the simplest cases of Right Node Raising (RNR), for example (27).

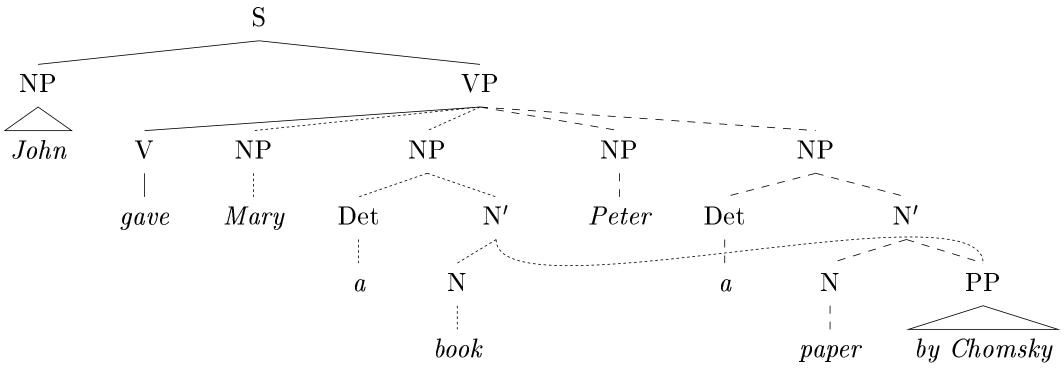
(27)



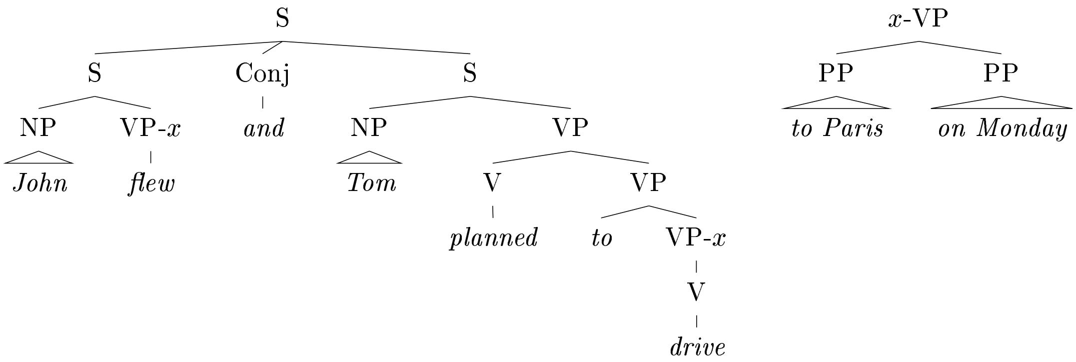
The RNR-ed material is represented as a fragment at the end, but note that it can be successfully zipped to the incomplete VPs of both conjuncts. (Although this is not the typical analysis for this type of sentence, it lets you have analyses for non-typical RNR sentences such as (28), where two constituents have been 'raised'.)

However, RNR introduces some new wrinkles, since the coordinated structures do not need to show as strong a constraint of parallelism as the examples we have been considering so far. In particular, as example (28) shows, the 'raised' node(s) may come from different levels in the different coordinated constituents. Nevertheless, we take it as vital that the shared structure – here the 'raised' node(s) – are being given the same syntactic structure across the entire parse. While many phenomena such as binding that are defined in terms of tree structure are defined differently in LFG (such as by using relationships of f-structure, argument structure and linear order), note that

(25)



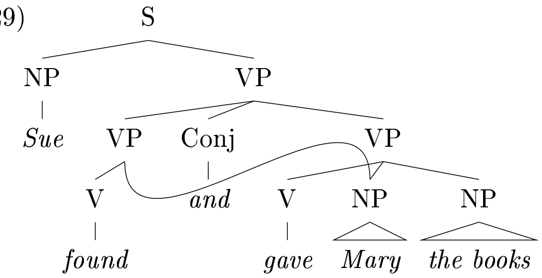
(28)



our representation of RNR is nevertheless consistent with the arguments of Blevins, McCawley and others that so-called Right Node Raised constituents actually behave as if they are low down in the syntax tree and not in some raised up right peripheral position (as was common in early transformational grammar analyses).

A basic and correct prediction of our account is that RNR only happens at the right periphery,[5] and that all instances of coordination observe the usual word order constraints of the language. In contrast, this does not follow from a right-extraction analysis of RNR. Our account does not require any further stipulations to rule out a structure like (29), unlike, say, the multidomination account of McCawley (1982).

(29)

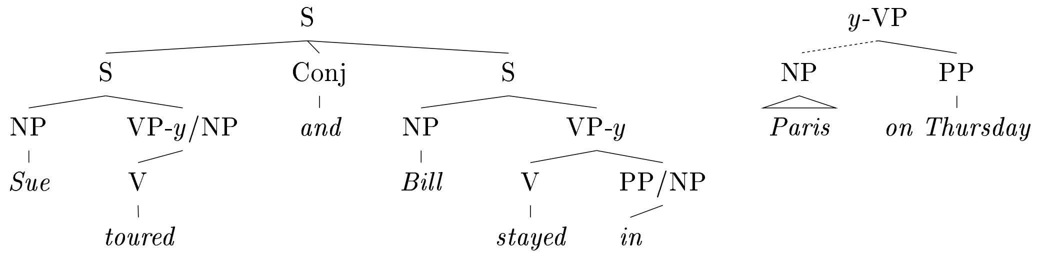


Something that is not explained by what we have presented so far is that RNR can occur with a constituent belonging to mother nodes of different categories, as in (30). Here the first element of the RNRed fragment belongs to a VP in the first conjunct and a PP in the second.

(30) Sue toured and Bill stayed in Paris on Thursday.

Apparently not all languages allow this freedom in RNR. Jim Blevins (p.c., 1996) drew to our attention McCloskey (1986), which notes in passing that in Modern Irish, Spanish, and Polish, RNR can only occur from a PP providing that there is a PP in each constituent. While further investigation is required, perhaps our theory would be suitable as it stands for such languages. However, some additional flexibility is clearly required to handle English.

[5]Or mutatis mutandis, at the left periphery to account for certain Left Node Raising constructions such as *Sam wanted John's [[mother to leave] and [best friend's brother to stay]]*.

(31) 

Examples like (30) show that what is being coordinated cannot always be represented simply as the span between two states in a FSA. Rather, what is important is whether each conjunct does combine with the shared material to give a valid expansion of the appropriate phrase structure rules. This can be checked either by examination of each rule, or by using intersection of the regular languages to check that the RNRed material is a valid continuation of the incomplete rules in each conjunct.[6] Our basic intuition is that the coordination in (30) is valid because the NP can both complete the PP of the second conjunct and appear in the VP of the first conjunct, and the final PP is then also allowed in the VP of each conjunct. We propose to license this by allowing slash categories (in the tradition of GPSG and Categorial Grammar), as shown in (31).[7] The /NP in each incomplete S becomes part of the implicit stack of things to be zippered. The two partial Ss can be coordinated because they have the same stacks on the left and right (i.e., no stack on the left and a stack of VP-y above NP on the right). The reason that the coordinated S can be zippered with the fragment *Paris on Thursday* is because the dotted line indicates that the NP is part of the implicit stack of the fragment. That stack matches the stack of the coordinated S, and so they can be zippered into a complete S with no stacks.

Note that this innovation causes our account of RNR to overgenerate in various ways (ways also generated by Categorial analyses). For instance, native speakers appear not to get the reading for the sentence (32) that is shown with brackets, although our analysis generates it as in (33).

(32) [[I think that Harry] and [Barry]] will lend you money.

[6]Indeed, rather than working in terms of states of an FSA, it may be superior to think solely in terms of regular languages, in particular the suffix language of the states in the FSA, as was suggested to us by Ron Kaplan (p.c.).

[7]Alternatively, we could introduce an empty NP-0 category that was in the start state of the NP rule.

At the moment, however, we believe that it is best to see such constraints as following from notions of information structuring and intonational phrasing rather than syntactic constraints. This is in part because reversing the order of conjuncts (*Barry, and I think that Harry will lend you money*) helps appreciably (although one could argue that a parenthetical reading of *I think that* is at work here), and because the grammar must generate other similar structures such as *I think that Harry and Bill thinks that Barry will lend you money*.

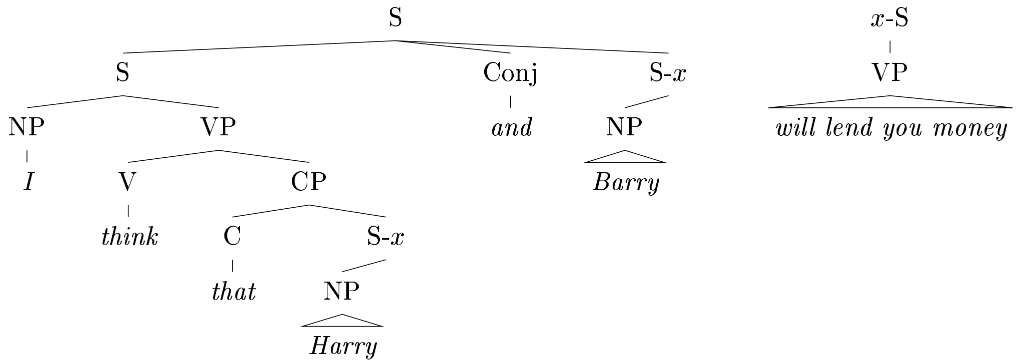
On the other hand, this proposal does predict that the RNRed material can have different Grammatical Functions in two clauses, as in sentences such as *John found, and gave Mary, the books*; *Bill gave Mary and she later read a book about ecological gardening*; or *Fred collects, and Ethel is an acknowledged authority on, Rembrandt etchings*.[8] It also licenses a coordination in the RNRed material as well as the material prior to it as in examples such as: *George talked about, and Bill also discussed, trade with the Russian ambassador and war with the Japanese general* or *Bill walked around and Fred also visited Munich yesterday and Paris today*. RNR also interacts correctly with conjunction reduction, as shown in (34).

Distribution in f-structures

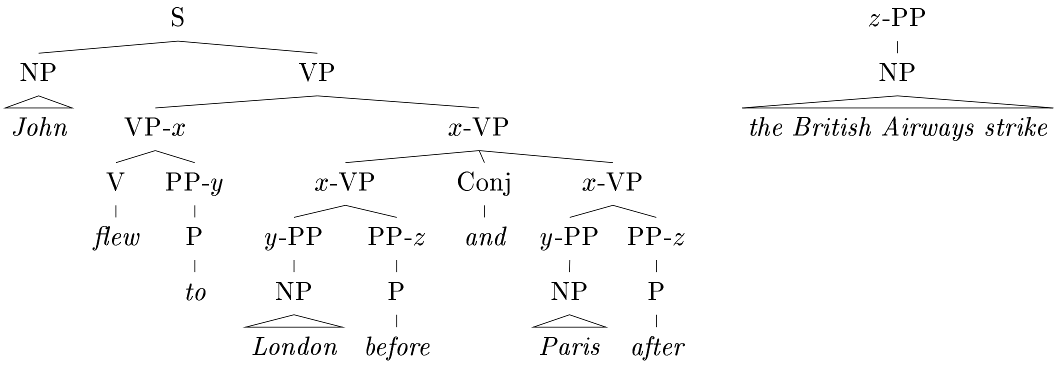
An important goal of the early work on constituent coordination in LFG was that by using a set representation for conjunctions, information outside the conjunction would automatically distribute correctly, without things outside the conjunction even needing to know that a conjunction was present. So in (35a), the subject is annotated

[8]This is because the f-structure that gets put into the right projection is the one under the OBJ for *John found* and the one under the OBJ2 for *gave Mary*. Thus, even though both conjuncts gets a VP/NP in the c-structure, the f-structures are different. (One way to see how this works is to imagine what happens if you instead insert the empty NP-0 node alluded to in footnote 7 instead of using a slash category. The slash category has the same effect.)

(33)

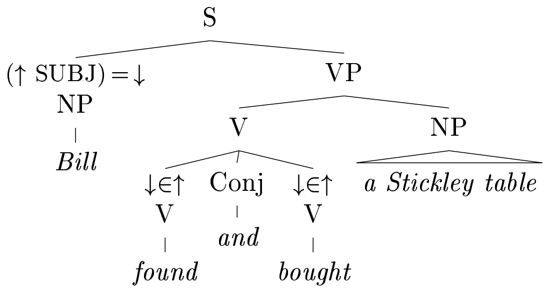


(34)

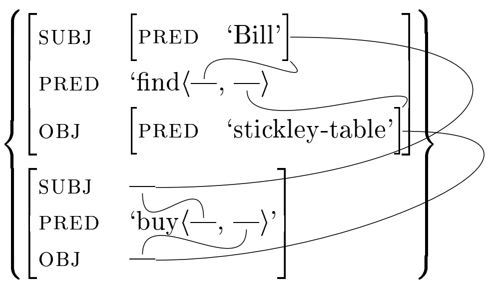


with (↑ SUBJ) = ↓ as usual, but this information actually gets distributed over the set elements as in (35b), without anything special having been said.

(35) a.



b.



Technically, this was done by defining function application involving sets via generalization (the greatest lower bound operation in the subsumption ordering on the f-structure lattice):

$$\text{For a set } s, \quad (s\ a) = \sqcap_{f \in s}(f\ a)$$

Thus the equation (↑ SUBJ) = ↓ ends up asserting a statement about the generalization of a set of f-structures, which necessarily means that each f-structure individually must satisfy this requirement.

One correct consequence of distributing constraints over sets is that consistency constraints are checked individually in each set. Thus the account can explain the French data in (36c–d):

(36) a. Jean l'a frappé.
Jean him.ACC struck

b. Jean lui a donné des coups de pied.
Jean him.DAT kicked

c. Jean {*lui/*l'} a frappé et donné des coups de pied.

d. Jean m'a frappé et donné des coups de pied.
'Jean struck me and kicked me.'

Examples (36a–b) show that the verbs are selecting accusative and dative case respectively for their patient object. (36c) then shows that using either the accusative or dative third person clitic is thus bad because it will conflict with the case selected by the lexical entries of one of the verbs. However, (36d) is well-formed – *me* is underspecified and can be either an accusative or dative clitic, and so it is consistent at f-structure with the demands of each conjunct.

This account in terms of set generalization continues to work without change with the account of non-constituent coordination that we have developed. For example, the sentence (37a) will have the functional annotations in (38), yielding the correct f-structure shown in (37b).

(37) a. John gambled in Sydney on Monday and in Monaco on Thursday.

b.
$$\left\{ \begin{array}{l} \begin{bmatrix} \text{SUBJ} & [\text{PRED 'John'}] \\ \text{PRED} & \text{'gamble}\langle\text{—}\rangle\text{'} \\ \text{TENSE} & \text{PAST} \\ \text{ADJ} & \left\{ \begin{array}{l} \begin{bmatrix} \text{PRED} & \text{'in}\langle\text{—}\rangle\text{'} \\ \text{OBJ} & [\text{PRED 'Sydney'}] \end{bmatrix} \\ \begin{bmatrix} \text{PRED} & \text{'on}\langle\text{—}\rangle\text{'} \\ \text{OBJ} & [\text{PRED 'Monday'}] \end{bmatrix} \end{array} \right\} \end{bmatrix} \\ \begin{bmatrix} \text{SUBJ} & \text{—} \\ \text{PRED} & \text{'gamble}\langle\text{—}\rangle\text{'} \\ \text{TENSE} & \text{PAST} \\ \text{ADJ} & \left\{ \begin{array}{l} \begin{bmatrix} \text{PRED} & \text{'in}\langle\text{—}\rangle\text{'} \\ \text{OBJ} & [\text{PRED 'Monaco'}] \end{bmatrix} \\ \begin{bmatrix} \text{PRED} & \text{'on}\langle\text{—}\rangle\text{'} \\ \text{OBJ} & [\text{PRED 'Thursday'}] \end{bmatrix} \end{array} \right\} \end{bmatrix} \end{array} \right\}$$

This analysis correctly predicts that if a verb is distributed over a set, then the verb must appear with the same PRED, that is with the same subcategorization frame, in each element of the set. So, on our account, a sentence like (39) is ruled out not at c-structure (where a perfectly well-formed coordination of two segments of the VP rule is generated), but rather at f-structure. In other words, non-parallelism of conjuncts is permitted (as we saw earlier) if it involves simply adding adverbs or reordering complements, but the f-structure enforces the constraint that a shared verb must have the same subcategorization frame realized in each conjunct.

(39) *Sue gave Sarah a book and a CD to Melanie.

However, there are some problems lurking in the generalization-based account of Kaplan and Maxwell (1988) that we seek to correct here. Under that account, an example like (40) fails to have a well-formed f-structure.

(40) John wanted and Bill wanted to go.

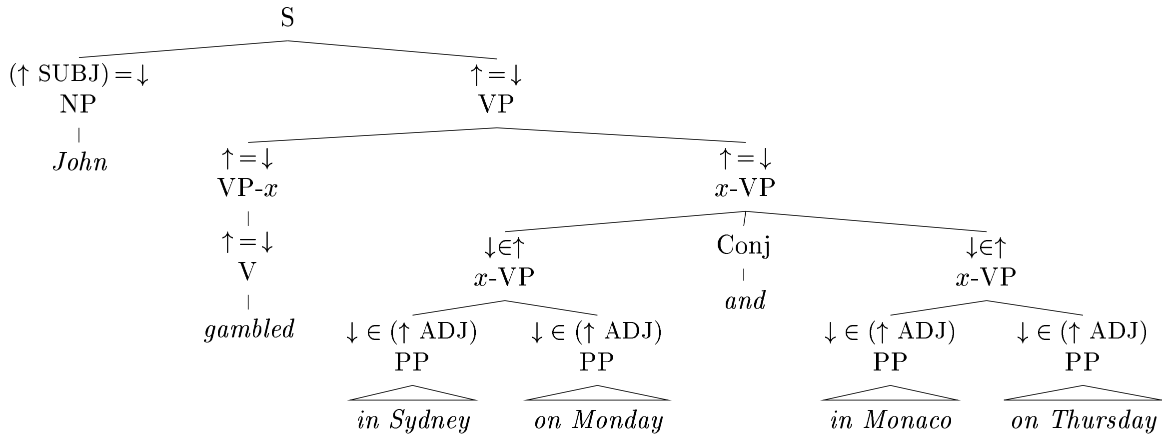
This is because the generalization of the SUBJ of *to go* is empty – the functional control equation on each verb *want* specifies a different value for the controlled subject of *go*, and the generalization of these different values is the empty f-structure. Thus the f-structure corresponding to *to go* is incomplete. To get the right behavior in examples like this, we dispense with use of generalization, and instead employ simply subsumption and the distribution of completeness constraints. In other words, we redefine application expressions for sets in terms of subsumption as follows:

$$\text{For a set } s, \forall f \in s, \quad (s\ a) \sqsubseteq (f\ a)$$

The original motivation for using generalization instead of only subsumption in Kaplan and Maxwell (1988) was to provide an explanation as to why sentences like *John promised and persuaded Bill to go* are bad, on the argument that the f-structure corresponding to *to go* didn't have a consistent SUBJ. However, Mary Dalrymple (p.c.) has argued that the reason that this 'promised and persuaded' sentence is bad is because of the difference between subject and object control, not because there isn't a consistent SUBJ for *to go*. So we now revert to the idea that attributes distribute over sets using subsumption instead of generalization, and add the idea that completeness and other constraining equations get distributed over sets as well. (This is to prevent sentences like **John gave Mary an apple and Bill*.) Semantic forms get subsumed when they are distributed, so that, for (40), each element in the set gets a copy of the semantic form for *to go*, which fills in the SUBJ differently. Since each of the copies are complete, the original semantic form for *to go* is considered complete, and the sentence is good.

Secondly, we need to explain in more detail how distribution works when there are constituents with stacks of states. For a (partial) constituent, the f-structures for the left states are stacked in a left projection and the f-structures for the right states are stacked in a right projection. When it comes time to coordinate two constituents with stacks, new projections are constructed for each side by making a stack of sets, where the set for the i^{th} item in the stack consists of the i^{th} items of the corresponding stacks in the left and right daughters. Then, when a coordinated partial constituent is concatenated with a following partial constituent, the right projection of the coordinated constituent is unified with the left projection of the other constituent. This causes the non-coordinated material to be distributed at the correct levels. This is important in a sentence like (41) because we want the predicate for *in* to

(38)



be distributed across *Sydney* and *Monaco* even though they are inside an ADJUNCT set and are not otherwise accessible from the VP f-structure at the top (the desired f-structure is again (37b)). In addition, this example again needs the new definition of distribution, since otherwise *in* doesn't get a consistent argument for its OBJ.

(41) John gambled in [Sydney on Monday] and [Monaco on Thursday].

Thirdly, when there are two or more conjunctions in a sentence, the previous proposal does not actually deliver the right results. What one wants is a cross-product operation, so that the sentence in (42a) would be represented by a set of four f-structures, as in (42b) (where we have resorted to the PATR notation of boxed numerals to denote sharing, rather than the standard linking lines of LFG). This result is not actually delivered by the implementation of coordination defined in Kaplan and Maxwell (1988). To see this note that the lefthand part will produce a set of two (incomplete) f-structures, one for flying and one for driving. The righthand side also produces a set of two (incomplete) f-structures. What you get when you unify these two sets is a set with four incomplete elements (unification behaves like set union in this case). The problem becomes clearer if you consider two sets of three elements each: what you want is a set with nine elements (the cross-product), but what you get is a set with six incomplete elements (the union).

To get the desired result we would like to distribute one set over the other using subsumption, just like we distribute attributes over sets using subsumption. When the set is distributed to each f-structure element using subsumption, then recursively we want to distribute the f-structure element over the subsumed set in the standard way. One way to cause sets to be distributed over sets is to add indices to each set relation to indicate which set that an element belongs to, and to then use this information whenever the two sets are unified to cause the elements of one set to be distributed across the elements of the other set using subsumption (or vice versa). For (41a), if f_1 represents the partial f-structure corresponding to *John flew to*, f_2 represents *Bill drove to*, f_3 represents *Amsterdam on Monday* and f_4 represents *Brussels on Wednesday*, then we get:

$$f_1 \in_i \uparrow \quad f_2 \in_i \uparrow \quad f_3 \in_j \uparrow \quad f_4 \in_j \uparrow$$

When we are done, we end up with a set consisting of two sets. This gives us two different solutions, depending on which set distributes over which set:

Solution 1

$$\begin{array}{l}
f_1 \in_i \uparrow \wedge f_3 \in_j \uparrow \ \rightarrow f_3' \in_j f_1 \rightarrow f_1 \sqsubseteq f_3' \\
f_1 \in_i \uparrow \wedge f_4 \in_j \uparrow \ \rightarrow f_4' \in_j f_1 \rightarrow f_1 \sqsubseteq f_4' \\
f_2 \in_i \uparrow \wedge f_3 \in_j \uparrow \ \rightarrow f_3'' \in_j f_2 \rightarrow f_2 \sqsubseteq f_3'' \\
f_2 \in_i \uparrow \wedge f_4 \in_j \uparrow \ \rightarrow f_4'' \in_j f_2 \rightarrow f_2 \sqsubseteq f_4''
\end{array}$$

Solution 2

$$\begin{array}{l}
f_3 \in_j \uparrow \wedge f_1 \in_i \uparrow \ \rightarrow f_1' \in_i f_3 \rightarrow f_3 \sqsubseteq f_1' \\
f_3 \in_j \uparrow \wedge f_2 \in_i \uparrow \ \rightarrow f_2' \in_i f_3 \rightarrow f_3 \sqsubseteq f_2' \\
f_4 \in_j \uparrow \wedge f_1 \in_i \uparrow \ \rightarrow f_1'' \in_i f_4 \rightarrow f_4 \sqsubseteq f_1'' \\
f_4 \in_j \uparrow \wedge f_2 \in_i \uparrow \ \rightarrow f_2'' \in_i f_4 \rightarrow f_4 \sqsubseteq f_2''
\end{array}$$

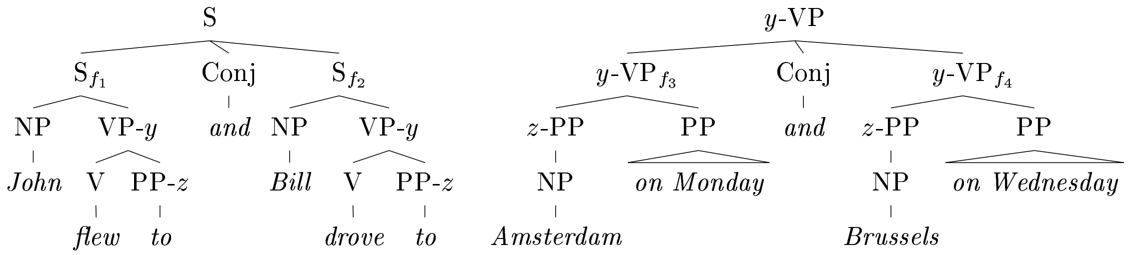
For example, for Solution 1, we have:

$$\uparrow\{f_1\{f_3', f_4'\}, f_2\{f_3'', f_4''\}\}$$

where f_3' is subsumed by f_1 and f_3, f_4' is subsumed by f_1 and f_4, f_3'' is subsumed by f_2 and f_3, and f_4'' is subsumed by f_2 and f_4. In both cases you end up with $\uparrow$ being a set consisting of two sets of two elements.

This result of sets of sets differs slightly from the 'desired' result shown above, but is actually what we want. Consider for example the sentence:

(42) a.



b.
$$\left\{\begin{array}{ll}
\left[\begin{array}{ll}
\text{SUBJ} & \boxed{1}\left[\begin{array}{ll}\text{PRED} & \text{'John'}\end{array}\right] \\
\text{PRED} & \text{'fly}\langle —, — \rangle\text{'} \\
\text{OBL} & \boxed{2}\left[\begin{array}{ll}\text{PRED} & \text{'to}\langle — \rangle\text{'} \\ \text{OBJ} & \left[\begin{array}{ll}\text{PRED} & \text{'Amsterdam'}\end{array}\right]\end{array}\right] \\
\text{ADJ} & \boxed{3}\left\{\left[\begin{array}{ll}\text{PRED} & \text{'on}\langle — \rangle\text{'} \\ \text{OBJ} & \left[\begin{array}{ll}\text{PRED} & \text{'Monday'}\end{array}\right]\end{array}\right]\right\}
\end{array}\right]
&
\left[\begin{array}{ll}
\text{SUBJ} & \boxed{1} \\
\text{PRED} & \text{'fly}\langle —, — \rangle\text{'} \\
\text{OBL} & \boxed{5}\left[\begin{array}{ll}\text{PRED} & \text{'to}\langle — \rangle\text{'} \\ \text{OBJ} & \left[\begin{array}{ll}\text{PRED} & \text{'Brussels'}\end{array}\right]\end{array}\right] \\
\text{ADJ} & \boxed{6}\left\{\left[\begin{array}{ll}\text{PRED} & \text{'on}\langle — \rangle\text{'} \\ \text{OBJ} & \left[\begin{array}{ll}\text{PRED} & \text{'Wednesday'}\end{array}\right]\end{array}\right]\right\}
\end{array}\right]
\\
\left[\begin{array}{ll}
\text{SUBJ} & \boxed{4}\left[\begin{array}{ll}\text{PRED} & \text{'Bill'}\end{array}\right] \\
\text{PRED} & \text{'drive}\langle —, — \rangle\text{'} \\
\text{OBL} & \boxed{2} \\
\text{ADJ} & \boxed{3}
\end{array}\right]
&
\left[\begin{array}{ll}
\text{SUBJ} & \boxed{4} \\
\text{PRED} & \text{'drive}\langle —, — \rangle\text{'} \\
\text{OBL} & \boxed{5} \\
\text{ADJ} & \boxed{6}
\end{array}\right]
\end{array}\right\}$$

(43) John gave a book or lent a record to Mary on Wednesday and to Sue on Friday.

This sentence has two readings depending on whether the disjunction or conjunction has wider scope (Blevins (1994) argues that the wide scope reading for the disjunction is the most natural interpretation, but we tend to think the opposite). These two readings correspond precisely to the two solutions indicated above.

SGF-coordination, and subject-gapping more generally

This paper has presented an analysis of the main cases of constituent coordination, conjunction reduction, and Right-Node Raising in English. While coordinations have an f-structure representation that impose some constraints on what can be coordinated, a central part of our analysis is that the forms of possible coordinations are determined by surface structure – in particular, by the "what you see is what you get" surface structure of LFG. This raises interesting questions about the adequacy of the analysis in the face of certain phenomena which do not appear to obey this "surface coordination" condition, and which other frameworks have analyzed by using underlying structures and subsequent movements, or similar devices. One phenomenon of this sort that has been widely discussed is the so-called SGF (subject gap finite) coordination in German (Höhle 1983), as shown in (44):

(44) a. In den Wald ging der Jäger und
into the forest went the hunter and
fing einen Hasen
caught a rabbit
'The hunter went into the forest and caught a rabbit.'

b. Gestern ging der Jäger in den Wald
yesterday went the hunter into the forest
und fing einen Hasen
and caught a rabbit
'The hunter went into the forest yesterday and caught a rabbit.'

These coordinations are not of the A [X and Y] B form because the (shared) subject is in the middle of the first conjunct rather than being in one of the margins (note that the Vorfeld item is construed with only the first conjunct). Steedman (1990) assimilated this construction to gapping, but one cannot similarly gap an object or both the subject and the object (Kathol 1995), and this construction does not seem to have the register/intonation associations of gapping, so such an analysis seems wrong. The ability to stack conjuncts also suggests that the second clause is not an adjunct.

Kathol (1993, 1994, 1995) has produced a series of analyses of this construction within HPSG, which attempt to assimilate it to other cases of coordination, as just being VP-coordination, except that the coordination happens at a deeper level before the linearization effects of German have produced the well-known V2 and V1 orders. Overall, we feel that this attempt has failed, in that even in its most recent version (Kathol 1995), the theory still has an essentially disjunctive character, with one clause for cases of "normal" coordination, and a second clause to handle SGF-coordination. On the other hand, we believe the account is essentially right in suggesting that this is coordination at a deeper level than surface structure. It seems that in general languages with a VSO word order always allow such perhaps wrongly named "VP-coordination" either of the form *S and VP* or *VP and S* depending on other parameters of the language. For instance, in Chamorro, Chung (1990) argues that only constituents of the same category can be conjoined and that RNR is limited to a single constituent (although these are both things that have been found to be wrong in English). Chung then notes that Chamorro has what she regards as coordinated VPs (although note that both verbs have finite inflections on them):

(45) [Man-aflitu guihan] yan [mam-a'tinas
Infl(s).AP-fry fish and Infl(s).AP-make
fina'denni'] i mismu patgun
hot.sauce the same child
'The same child fried fish and made hot sauce.'

The problematic data is that the subject need not appear at the end as in (45), but can appear inside any conjunct, as shown in (46). Chamorro word order is most commonly VSO (though Chung analyzes it as 'underlyingly' VOS).

(46) a. [Man-aflitu guihan] yan [mam-a'tinas
Infl(s).AP-fry fish and Infl(s).AP-make
i mismu patgun fina'denni']
the same child hot.sauce
'The same child fried fish and made hot sauce.'

b. [Man-bokbuk pälu cḧguan] yan
Infl(s).AP-uproot some weed and
man-anum si nana-hu pälu
Infl(s).AP-plant mother-Agr(1s) some
flores] ya [ha-usa i pala]
flower and.then Infl(3s).use the shovel
'My mother dug some weeds and planted some floweres and used [i.e., with] her shovel.'

We omit details, but Chung provides quite good arguments that this cannot be IP conjunction with zero anaphora or RNR. Thus again it seems that we have a special form of sentential coordination that allows subject sharing. Tagalog under Kroeger's (1993) analysis provides a third example.

This suggests to us that we do need a disjunctive theory of coordination where one possibility is the kind of surface structure coordination that we have been examining in English, and the other is a coordination resulting in the sharing of subjects at f-structure. For the present we will assume that a suitable formalization of this approach is right for such data, but we clearly need to examine coordination in languages with VSO and other word orders much more thoroughly in order to be able to evaluate this hypothesis more satisfactorily.

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