preprint. published version in: Gärtner, Hans-Martin. 2002. *Generalized Transformations and Beyond*. Berlin: Akademie-Verlag. 119-145.

3.2 Varieties of Multiconstituency and Multidominance

This section introduces some varieties of "multiconstituency" and "multidominance" (MC/MD) recognized in linguistics. Presentation will be neither comprehensive nor particularly deep, given the rather special use I want to make of MC/MD later.

Note, to begin with, that Chomskyan generative syntax tends to be developed with reference to structures equivalent to "trees" as defined in (14) of section 2.3, repeated here as (5) for convenience (Partee et al. 1993, p.441f).

(5) A *constituent structure tree* is a mathematical configuration $< N, Q, D, P, L >$, where
N is a finite set, the set of nodes,
Q is a finite set, the set of labels,
D is a weak partial order in $N \times N$, the dominance relation,
P is a strict partial order in $N \times N$, the precedence relation,
L is a function from N into Q, the labeling function,
and such that the following conditions hold:
(1) $(\exists x \in N)(\forall y \in N)[<x,y> \in D]$ (Single Root Condition)
(2) $(\forall x,y \in N)[(<x,y> \in P \vee <y,x> \in P) \leftrightarrow (<x,y> \notin D \wedge <y,x> \notin D)]$ (Exclusivity Condition)
(3) $(\forall w,x,y,z \in N)[(<w,x> \in P \wedge <w,y> \in D \wedge <x,z> \in D) \rightarrow <y,z> \in P]$ (Nontangling Condition)

However, this is not a matter of principle, as the following quote illustrates.

> “Still, we can ask whether D-structures, S-structures, etc., have the properties of tree structures. Insofar as they are determined by X-bar theory, this will be the case. But there are other factors that enter into determining their properties. Reanalysis and restructuring processes, for instance, may yield phrase markers that cannot be represented as tree structures. [. . .] Furthermore, X-bar theory can be constructed so that it does not require that phrase markers have tree properties. It has occasionally been suggested that coordination might be understood in terms of union of phrase markers (in effect, three-dimensional projection), linear order being determined by a “spell-out“ rule. The assumption would be, then, that if the very same language were to be used in a medium having a dimension in addition to linear time, this “spell-out“ rule would be unnecessary. Such suggestions might be correct, and I think they merit examination. Much more radical departures from tree structures can be, and sometimes have been, proposed. I will not explore these questions here, but merely note that incompatibility of such proposals with the theory of phrase structure grammar stands as no barrier to them“ (Chomsky 1982, p.14f).[2]

Now, trees are a special type of graphs. Following Cormen et al. (1990, p.86ff), one may also call the objects defined in (5) “rooted, directed, anticyclic, ordered graphs

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[2] This passage is also quoted by Blevins (1990, p.4), who employs graphs, called “mobiles,“ that allow both discontinuous constituents and MC/MD. A different type of multidimensional phrase-structure is employed by Haegeman&van Riemsdijk (1986) in their analysis of verb projection raising. Their mechanism of “reanalysis“ allows a sequence of categories to possess several (conflicting) phrase-structural analyses at one and the same time. See Kolb (1997b) for arguments that even the proper analysis of adjunction requires structures richer than trees.

(with self-loops).“[3] The set-based objects defined in Chomsky (1995a, chapter 4), and the modified objects I will introduce in section 3.3, could be translated into rooted, directed, acyclic, (unordered) graphs. Of course, it has to be shown how linear precedence can be computed on the basis of unordered graphs, a question that equally arises for the set-based minimalist structures (cf. sections 2.6.2 and 3.4.3).

The first step toward MC/MD, however, consists in abandoning the so-called “Single Mother Condition“ (SMC), (8), sometimes also called “Nonlooping Condition.“[4] From the perspective of trees, this condition is definable in terms of “immediate dominance“ (7), itself based on dominance via the notion of “proper dominance“ (6).

(6) Proper Dominance
$(\forall x,y \in N)[\ xPDy \leftrightarrow xDy \wedge x \neq y\ ]$

(7) Immediate Dominance
$(\forall x,y \in N)[\ xIDy \leftrightarrow (\ xPDy \wedge \neg\ (\exists z \in N)[\ xPDz \wedge zPDy\ ]\ )\ ]$

(8) Single Mother Condition (SMC)
$(\forall x,y,z \in N)[\ (\ xIDz \wedge yIDz\ ) \rightarrow x = y\ ]$

What keeping or abandoning (8) implies can be made more tangible if one considers the directedness of immediate dominance. Thus, in the language of graph-theory, a pair of nodes <x,y> (∈ ID) defines an “edge“ that “leaves“ x and “enters“ y. One can count the number of edges entering a node, arriving at the “in-degree“ of a node, and the number of edges leaving a node, the “out-degree“ (Cormen et al. 1990, p.87). Minimalist syntax takes the in-degree of nodes to lie invariably at 1, except for root nodes, whose in-degree is 0. The out-degree lies invariably at 2, i.e. structures are “binary branching,“ except for terminals, whose out-degree equals 0.[5] Thus, abandoning the Single Mother Condition amounts to allowing in-degrees of any finite integer n, ($n \geq 1$), except for root nodes, which by definition keep their in-degree at 0.

Formally, given (6) and (7), the SMC is a logical consequence of the definition of trees in (5).[6] To show this, we assume (9) holds.

(9) $aIDc \wedge bIDc \wedge a \neq b$

Applying the definitions of ID and PD, we can derive (10).

(10) $\neg(aDb) \wedge \neg(bDa)$

---

[3] “Directedness“ is usually represented not by arrows but by top-down orientation of the graph on the page. “Anticyclicity“ seems to be an appropriate term for graphs that only allow cycles of length 1, i.e., cycles that are “self-loops.“

[4] Cf. McCawley (1968, p.244), Barker&Pullum (1990, p.20), and Blevins (1990, p.48).

[5] For a recent approach appealing to ternary branching see Brody (1998).

[6] Cf. Barker&Pullum (1990, p.20).

Thus, nodes violating the SMC could not be ordered wrt to each other in terms of D. It then follows from the Exclusivity Condition on trees that they must be ordered wrt each other in terms of P, that is, (11) holds.

(11) $(aPb) \vee (bPa)$

From the Nontangling Condition on trees we know that ordering two nodes in terms of P orders whatever these nodes dominate in the same way. Thus, given (9) and (11) we get (12).

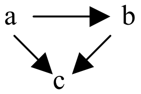
(12) cPc

(12) is in conflict with the requirement on P to be irreflexive. So we derive contradiction (13) and have an indirect proof that the SMC follows from the definitions of "constituent structure tree," PD, and ID.

(13) $cPc \wedge \neg(cPc)$

As (10) indicates, one special case of MC/MD is filtered out by the definition of immediate dominance right away.[7] Thus, consider the following graph.

(14)



This could represent the proper dominance relation given in (15).

(15) $aPDb \wedge aPDc \wedge bPDc$

(15), however, directly prevents an interpretation of (14) as representing an ID relation, given the definition of immediate dominance. The (minimal) ID representation compatible with (15) is (16) instead.

(16) $a \longrightarrow b \longrightarrow c$

Crucially, (14) is a subcase of the kind of structure that canonically arises if movement constructions or chains are captured by means of MC/MD. This has been indicated in section 2.7.3 already. Thus, if one wants to interpret the relation in (14) as immediate dominance relation, it is not enough to abandon the SMC. ID has to be taken as a

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[7] Thanks to Tom Cornell (p.c.) for directing my attention to this issue.

defining primitive of the graphs employed. Let us call the appropriate structures "rooted MC/MD-graphs."[8]

(17) A *rooted MC/MD-graph* is a pair <N,ID>, where
N is a finite set, the set of nodes,
ID is a binary relation on N, the immediate dominance relation,
and such that
(1) ID^+ is irreflexive (Acyclicity)
(2) $(\exists x \in N)(\forall y \in N)[\langle x,y \rangle \in ID^*]$ (Single Root Condition)

ID^+ will also be called "proper dominance relation," PD, and ID* "dominance relation," D. On the basis of (17), (14) and (16) can now be distinguished insofar as they represent different rooted MC/MD-graphs, namely, the ones in (18a) and (18b) respectively.

(18) a. <{a, b, c}, {<a,b>, <a,c>, <b,c>}>
b. <{a, b, c}, {<a,b>, <b,c>}>

Clearly, this distinction could not be made on the basis of D (= ID*), where they "collapse" into (19).[9]

(19) a. <{a, b, c}, {<a,a>, <a,b>, <a,c>, <b,b>, <b,c>, <c,c>}>

Let us now turn to the issue of precedence and its relation to MC/MD structures. Most radically, one could dispense with P, i.e. work with unordered graphs like the ones defined in (17) (cf. Barker&Pullum 1990). There would then be no equivalent to the Exclusivity Condition or Nontangling Condition on trees. What is required in this case is some kind of sorting algorithm that linearizes the terminals at the (interface to the) PHON-component. As already indicated in section 2.6.2, Chomsky (1995a, section 4.8) proposes to implement Kayne's (1994) LCA, for the purpose of translating asymmetric c-command into linear precedence.

Alternatively, one can define *ordered* MC/MD structures, two variants of which I will discuss here. The first one, developed by McCawley (1968) and employed by Blevins (1990), consists in giving a strict linear ordering of *terminal* nodes. On the basis of this ordering, a partial precedence relation on non-terminals can be induced. The result is constrained by a "Partial Exclusivity Condition." The second approach is taken by Peters&Ritchie (1981), who define a strict linear ordering for each set of *sister* nodes in their own version of MC/MD structures, called "linked trees."

Let us start off with the former system. I'll develop this approach in terms of MC/MD-graphs as defined in (17). Thus, assume we have added a strict partial ordering

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[8] Cf. the definition of "acyclic graphs" in Kracht (2001). I disregard labeling here. I adopt the convention that for any relation R, R^+ denotes the transitive closure of R and R^* denotes the reflexive transitive closure of R.

[9] The definitions of "labeled graph" (Barker&Pullum 1990, p.20) and "mobile" (Blevins 1990, p.49) seem to neglect this point.

on N, the “precedence relation“ P, and thereby obtained a triple <N,ID,P>, the basis of “*ordered*, rooted MC/MD-graphs.“
We then define the set of terminals, T, as a subset of N.

(20) Terminals
$(\forall x \in N)[\ x \in T \leftrightarrow \neg(\exists y \in N)[\ <x,y> \in ID\ ]\ ]$

Next, we require the set of terminals to be linearly ordered (cf. Blevins 1990, p.50).

(21) $(\forall x,y \in T)[\ x \neq y \rightarrow (\ <x,y> \in P \vee <y,x> \in P\ )\ ]$

A linguistically sound projection of P onto non-terminals further requires a weakened Exclusivity Condition, given in (22).

(22) Partial Exclusivity Condition (PEC)
$(\forall x,y \in N)[\ <x,y> \in ID^* \rightarrow (\ <x,y> \notin P \wedge <y,x> \notin P\ )\ ]$

Stating the “induction“ principle, i.e. the “Precedence Inheritance Condition“ requires some additional preparation.

Let's call the set of nodes dominated by a node x the “lower cone“ of x, abbreviated ⇣*x* (Cf. Grefe&Kracht 1996, p.3).

(23) Lower Cone
⇣x $=_{def}$ { y | <x,y> ∈ ID* }

Since ⇣x contains the nodes that make up the constituent with root node x, we will also speak of the “constituent“ ⇣x.[10] Also, we need the collection of nodes *properly* dominated by x, i.e. the “proper lower cone“ of x, abbreviated as ↓x.

(24) Proper Lower Cone
↓x $=_{def}$ { y | <x,y> ∈ ID^+ }

We further distinguish terminals from non-terminals wrt their “orderable lower cone,“ abbreviated as ⇓*x*.

(25) Orderable Lower Cone
$$⇓x =_{def} \begin{cases} ⇣x, \text{ if } x \in T \\ \downarrow x, \text{ if } x \in N\text{-}T \end{cases}$$

---

[10] Technically, it may be advantageous to define constituents not just as sets of nodes, but as (sub-)trees or (sub-)graphs, as done in Grefe&Kracht (1996, p.3). For an updated version of the latter, see Kracht (1999).

We now generalize precedence for sets of nodes in the following way. (X and Y are set variables.)

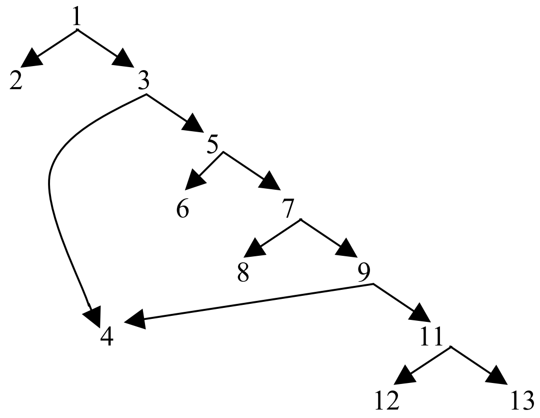
(26) Set Precedence
$\langle X,Y\rangle \in \mathbb{P} \Leftrightarrow_{\text{def}} (\forall x,y \in N)[\,(x \in X \wedge y \in Y) \rightarrow \langle x,y\rangle \in P\,]$

Finally, we can state the crucial "Precedence Inheritance Condition."[11]

(27) Precedence Inheritance Condition (PIC)
$(\forall x,y \in N)[\,\langle x,y\rangle \in P \leftrightarrow \langle \Downarrow x, \Downarrow y\rangle \in \mathbb{P}\,]$

The consequence of the PIC is that precedence relations among terminals will be "inheritable" into regions of the MC/MD-graph that aren't "disturbed" by multidominance. Let's have a look at an example in order to see what that means.

(28)



(28) shows the kind of structuring, we are essentially concerned with, given the purpose of capturing (unbounded) dependencies. Let us assume that the order of terminals is $\langle 2,6,8,4,12,13\rangle$. In linguistic terms, this could be taken to mean that no "overt raising" of 4 has taken place. The complete relation P on the set of terminals is given in (29).

(29) $P_T = \{\langle 2,6\rangle, \langle 2,8\rangle, \langle 2,4\rangle, \langle 2,12\rangle, \langle 2,13\rangle, \langle 6,8\rangle, \langle 6,4\rangle, \langle 6,12\rangle, \langle 6,13\rangle,$
$\langle 8,4\rangle, \langle 8,12\rangle, \langle 8,13\rangle, \langle 4,12\rangle, \langle 4,13\rangle, \langle 12,13\rangle\}$

This fulfills condition (21). Likewise, the PEC is (trivially) complied with, given that for each terminal x, $\langle x,x\rangle \in ID^*$ and $\langle x,x\rangle \notin P$, the latter preserving the irreflexivity of P. In addition, precedence inheritance is fulfilled, given the identity of $\Downarrow x$ and $\{x\}$ in

---

[11] The PIC is closely related to the Nontangling Condition on trees. This is revealed if the latter is reformulated as follows.
(i) Nontangling Condition (reformulated)
$(\forall x,y \in N)[\,\langle x,y\rangle \in P \rightarrow \langle \Downarrow x, \Downarrow y\rangle \in \mathbb{P}\,]$

the case of terminals. For example, the PIC states that $<2,6> \in P$ iff $<\{2\},\{6\}> \in \mathbb{P}$. The latter has been defined to be equivalent to the former via "Set Precedence."

Let's then have a look at the nonterminal 11. Can it be ordered wrt 4 for example, i.e. can we get $<4,11> \in P$, or $<11,4> \in P$? Clearly, we have $<\{4\},\{12,13\}> \in \mathbb{P}$, which is equivalent to $<\Downarrow 4,\Downarrow 11> \in \mathbb{P}$. Thus, we get $<4,11> \in P$ "by induction."

Exactly the same reasoning holds wrt 11 and the other terminals preceding 4. We can thus add <2,11>, <6,11>, and <8,11>. Next, if $<8,11> \in P$ holds, $<\Downarrow 8,\Downarrow 9> \in \mathbb{P}$ also holds, given that $<\{8\},\{4,11,12,13\}> \in \mathbb{P}$. The remainder of P will be completed in the same way.

Thus far, multidominance hasn't had any effect on the construction of P. Things change, however, if we reorder terminal 4 in (28) wrt the other terminals, such that ordering <2,4,6,8,12,13> results.

(30) $P_T = \{<2,4>, <2,6>, <2,8>, <2,12>, <2,13>, <4,6>, <4,8>, <4,12>, <4,13>, <6,8>, <6,12>, <6,13>, <8,12>, <8,13>, <12,13>\}$

Inducing precedence for 11 will work as before. However, integrating 9 is not straightforward. In order to get $<8,9> \in P$ we need $<\{8\},\{4,11,12,13\}> \in \mathbb{P}$. This is impossible, since $<4,8> \in P$, not <8,4>. Crucially, $4 \in \Downarrow 9$ still holds, although 4 has somehow "left" the constituent with root 9 as far as computing linear precedence is concerned. Conversely, $<9,8> \in P$ cannot hold either, given that among other things $12 \in \Downarrow 9$ but $<8,12> \in P$. Thus, 8 and 9 cannot be ordered wrt each other in terms of P. Indeed, 8 and 9 cannot be ordered wrt each other at all under these conditions, since $<8,9> \notin ID^*$ and $<9,8> \notin ID^*$.

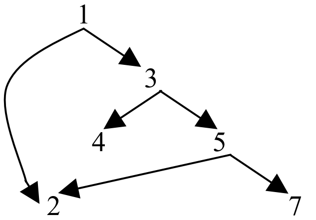
We now see why the Exclusivity Condition on trees has to be replaced by the Partial Exclusivity Condition if trees are replaced by ordered rooted MC/MD-graphs. Nodes that aren't ordered wrt each other in terms of ID* may be not ordered wrt each other in terms of P under specific circumstances.

Before going into the description of these "specific circumstances," let me repeat the main point of what has been established. One way of dealing with linear precedence within MC/MD syntax is to define *ordered* rooted MC/MD-graphs on top of their unordered counterparts. The result looks as follows (cf. McCawley 1968, Blevins 1990).

(31) An *ordered rooted MC/MD-graph* is a triple $\langle N,ID,P\rangle$, where
N is a finite set, the set of nodes,
ID is a binary relation on N, the immediate dominance relation,
P is a strict partial ordering on N, the precedence relation,
and such that
(1) ID^+ is irreflexive (Acyclicity)
(2) $(\exists x \in N)(\forall y \in N)[\langle x,y\rangle \in ID^*]$ (Single Root Condition)
(3) $(\forall x,y \in T)[x \neq y \rightarrow (\langle x,y\rangle \in P \vee \langle y,x\rangle \in P)]$
(Obligatory Ordering of Terminals)
(4) $(\forall x,y \in N)[\langle x,y\rangle \in ID^* \rightarrow (\langle x,y\rangle \notin P \wedge \langle y,x\rangle \notin P)]$
(Partial Exclusivity Condition)
(5) $(\forall x,y \in N)[\langle x,y\rangle \in P \leftrightarrow \langle \Downarrow x,\Downarrow y\rangle \in \mathbb{P}]$
(Precedence Inheritance Condition)

Now, multidominance results in P-unorderable pairs of nodes whenever there is “discontinuity.“ Take a very simple case like (32).

(32)



If the order of terminals in (32) is $\langle 2,4,7\rangle$, $\downarrow$5 is a discontinuous constituent. The yield of $\downarrow$5, i.e. 2+7, is not a substring of the entire string. For the yield of $\downarrow$1 is 2+4+7. 4 interrupts 2+7. We have already seen that it follows within ordered rooted MC/MD-graphs as defined in (31) that 4 and 5 are P-unorderable. $\langle \Downarrow 4,\Downarrow 5\rangle \notin \mathbb{P}$ and $\langle \Downarrow 5,\Downarrow 4\rangle \notin \mathbb{P}$. The general principle underlying “P-unorderability“ for pairs of nodes not ordered wrt each other in terms of ID* is given in (33).[12] Call this the “Precedence Disinheritance Condition.“[13]

---

[12] Recall that the ones that are ordered in terms of ID* are P-unorderable because of the Partial Exclusivity Condition.

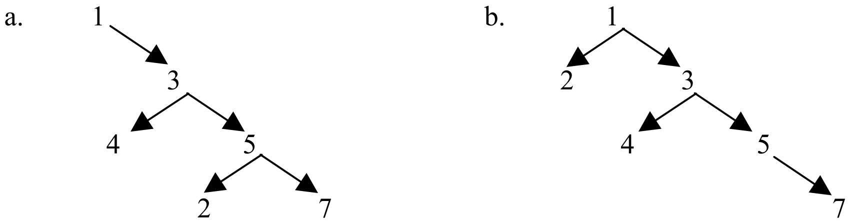
[13] The PDC follows from the PIC. Thus assume (i).
(i) $\langle a,b\rangle \in P \wedge \langle b,c\rangle \in P \wedge \langle d,a\rangle \in ID^* \wedge \langle d,c\rangle \in ID^* \wedge \langle d,b\rangle \notin ID^* \wedge$
$(\langle b,d\rangle \in P \vee \langle d,b\rangle \in P)$
Take (ii) as our first case. (ii) $\langle b,d\rangle \in P$. From this we derive (iii), given the PIC. (iii) $\langle \Downarrow b,\Downarrow d\rangle \in \mathbb{P}$. From (i) we can also derive (iv), given the PIC. (iv) $\langle \Downarrow a,\Downarrow b\rangle \in \mathbb{P}$. Now there are four subcases to consider: a) $a \in T$ and $b \in T$, b) $a \in T$ and $b \notin T$, c) $a \notin T$ and $b \in T$, and d) $a \notin T$ and $b \notin T$. Starting off with a), we derive (v) from (i). (v) $a \in \Downarrow d$. From (v) and (iii) together we get (vi), which contradicts (i). (vi) $\langle b,a\rangle \in P$ [$\bot$]. Considering subcase b), assume that $b^* \in \downarrow b$. From (iii) and (v) we derive (vii). (vii) $\langle b^*,a\rangle \in P$. However, (iv) yields (viii), which contradicts (vii). (viii) $\langle a,b^*\rangle \in P$ [$\bot$].

(33) Precedence Disinheritance Condition (PDC)

$$(\forall w,x,y,z \in N)[\ (<x,y> \in P \wedge <y,z> \in P \wedge \{x,z\} \subseteq \downarrow w \wedge y \notin \downarrow w\ ) \rightarrow \\ (\ <y,w> \notin P \wedge <w,y> \notin P\ )\ ]$$

Before introducing the second approach to precedence within MC/MD syntax, let us briefly look at the treatment of unbounded dependencies in terms of standard "movement." Thus, consider (34).

(34)



Construed in the most radical way, movement displaces a constituent. The essential difference between (32) and (34) can be captured in terms of the "proper upper cone" of a node.

(35) Proper Upper Cone

$$\uparrow x =_{def} \{y \mid <y,x> \in ID^{+}\}$$

The transition from (34a) to (34b) implies that $\uparrow 2$ is altered, as stated in (36).

(36) $\uparrow 2 = \{5,3,1\} \quad \Rightarrow \quad \uparrow' 2 = \{1\}$

Now assume that instead of deriving (34b) from (34a), (32) is derived. Then, $\uparrow 2$ remains constant.

(37) $\uparrow 2 = \{5,3,1\} \quad \Rightarrow \quad \uparrow' 2 = \{5,3,1\}$

Turning to case c) assume that $a^* \in \downarrow a$. (iii) and (v) then yield (ix). (ix) $<b,a^*> \in P$. From (iv) we derive (x), which contradicts (ix). (x) $<a^*,b> \in P$ [$\perp$]. Finally, in order to deal with case d) we assume that $a^* \in \downarrow a$ and $b^* \in \downarrow b$. From (iii) and (v) we conclude that (xi) holds. (xi) $<b^*,a^*> \in P$. (iv), however, yields (xii), which contradicts (xi). (xii) $<a^*,b^*> \in P$ [$\perp$].

Thus, we can conclude that assuming (ii) is incompatible with the PIC. In order to complete the indirect proof that the PDC follows from the PIC, we have to show that (xiii) as part of (i) is equally incompatible with the PIC. (xiii) $<d,b> \in P$ This can be shown in exactly parallel fashion, provided that c is replaced for a.

Drawing on the notion of "proper upper cone" (see (35), below) the effect captured by the PDC can be formulated somewhat more elegantly, but likewise more redundantly, in terms of the following principle. (R is a variable over P, "precedence," and its complement P', "succession.")

(xiv) Principle of Orientation Disturbance

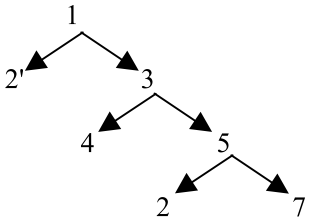
$$(\forall x,y,z \in N)[\ (\ <x,y> \in R \wedge z \in \uparrow x\ ) \rightarrow <y,z> \notin R\ ]$$

The type of dependencies just discussed observes the widely assumed c-command condition, which could therefore be rephrased as follows.[14]

(38) C-Command Condition on Dependencies
a. Move: $\uparrow x \subset \uparrow' x$
b. Multidominance: $\uparrow x = \uparrow' x$

However, as amply discussed earlier, minimalist syntax takes movement to involve copying and a chain relation between the "voyager" and its copy left behind. Thus, the "real" transition from (34a) under such a construal produces (39).

(39)



Again, c-command is observed, i.e. $\uparrow 2 \subset \uparrow 2'$. We have also already seen that identity is not the proper relation between 2 and 2' (cf. section 2.7.1). An identification of 2 and 2' is what underlies (32) instead, i.e. trees would have to be replaced by MC/MD-graphs.[15]

The c-command condition on dependencies expressed in terms of multidominance has been discussed in Barker&Pullum (1990, p.22) under the name of "Connected Ancestor Condition." I adapt their formulation to MC/MD-graphs.[16]

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[14] Monotonicity, constancy, or "syntactic compositionality" (Peter Staudacher p.c.), as revealed by this formulation of c-command, are all potential sources of simplicity. See Chametzky (1996) and Epstein (1999) for attempts to "explain" these properties of c-command.

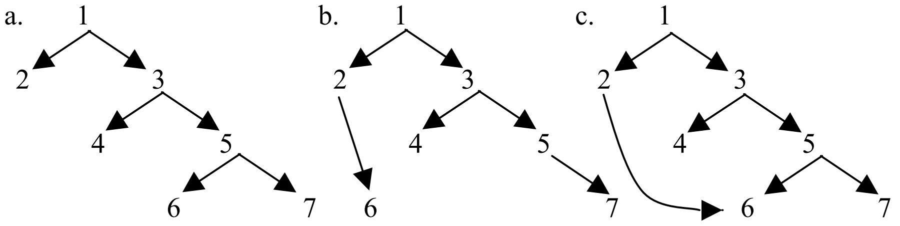
[15] See section 3.3 for further discussion of this. A formal analysis of the chain relation is beyond the scope of this work. See Kracht (2001). Let me simply note that one way of looking at chains would be to add another dimension to trees, e.g. a reflexive, transitive, symmetric relation E on N, called "enchain." Reflexivity gives us trivial chains per default. In addition one has to stipulate that copying leads to "enchainment." This could be formulated as follows.
(i) $(\forall x,y \in N)[\, Copy(x,y) \rightarrow <x,y> \in E \,]$
This gives rise to the following relation E for the tree in (39).
(ii) $E = \{<1,1>, <2',2'>, <3,3>, <4,4>, <5,5>, <2,2>, <7,7>, <2',2>, <2,2'>\}$
Of course, it is desirable to define chains over constituents rather than nodes. Also the copy relation is in need of further clarification. See Kracht (2001). For linguistic purposes, chains involving traces, resumptive pronouns, or parasitic gaps, as well as binding chains would have to be reviewed.

[16] See Barker&Pullum (1990) for the equivalence of MC/MD-graphs observing the CAC to trees wrt formal command properties. Under the obvious definition of "Upper Cone" in (i), the CAC can be reformulated as in (ii).
(i) Upper Cone
$\uparrow x =_{def} \{y \mid <y,x> \in ID^*\}$

(40) Connected Ancestor Condition (CAC)
$(\forall x,y,z \in N)[\ (\langle x,z\rangle \in ID \wedge \langle y,z\rangle \in ID) \rightarrow (\langle x,y\rangle \in ID^* \vee \langle y,x\rangle \in ID^*)\ ]$

Let us finally have a look at structures deviating from (38). Thus, transitions from (41a) to (41b)/(41c) can be defined.

(41)



(42) a. $\uparrow 6 = \{5,3,1\} \Rightarrow \uparrow' 6 = \{2,1\}$ [= (41b)]
b. $\uparrow 6 = \{5,3,1\} \Rightarrow \uparrow' 6 = \{5,3,2,1\}$ [= (41c)]

This time, $\uparrow' x$ includes "new information." Under displacement this leads to incongruent proper upper cones, i.e. $\uparrow x \not\subset \uparrow' x$ and $\uparrow' x \not\subset \uparrow x$ and $\uparrow x \neq \uparrow' x$. Again, under multidominance no information is lost. Thus $\uparrow x \subset \uparrow' x$.

The additional complication arising in (41) is, of course, correlated with the fact that from a derivational perspective, these transitions are counter-cyclic (cf. section 2.5.2). Only the former preserve c-command or the CAC. Thus, given my hypothesis 3, transitions like (41) will have to be avoided. The one problematic case, standing in the way of such an assumption, is X°-movement, to which I will return below (cf. 3.4.2).[17]

An alternative approach to linear order within MC/MD-syntax is developed in "phrase linking grammar" (PLG) as defined by Peters&Ritchie (1981) and adopted by Engdahl (1986).[18] The main innovation of PLG is to replace trees by "linked trees," which are defined as follows (Peters&Ritchie 1981, p.6; Engdahl 1986, p.44f).

(ii) Connected Ancestor Condition [reformulated]
$(\forall x,y,z \in N)[\ (x \in \uparrow z \wedge y \in \uparrow z) \rightarrow (x \in \Uparrow y \vee y \in \Uparrow x)\ ]$

[17] Another logically possible transition can be formulated as in (i).
(i) $\uparrow x \subseteq \uparrow' x$
This type of relationship is commonly called "lowering." An example would be the transition from (34b) to (34a), i.e. a reversal of the standard operation. Looking at it in terms of multidominance is one way toward trivializing the directionality involved in lowering. See Haider (1997) for discussion of whether the need to rule out such artifacts counts against the dynamical perspective of derivations.

[18] See also Joshi (1985) for some discussion of the formal properties of PLG and of how to add links to his own TAG framework.

(43) A *linked tree* is a finite set *N* of nodes (vertices) together with binary relations *I* (of immediate tree domination) and *L* (of immediate link domination) on *N*, and functions *P* (of left-to-right precedence) and *f* (which labels nodes with vocabulary symbols) having domain *N* and ranges contained respectively in $N \times N$ and $V_T \cup V_N$ satisfying conditions (i) - (v):

(i Linear Precedence Ordering of Siblings) P(n) is a strict linear ordering of $\{m \mid <n,m> \in I \cup L\}$ for all n in N,

(ii Root) there is an r in N such that $<r,n> \in I^*$ for all $n \in N$,

(iii Unique Tree Parent) I^{-1} is a partial function defined just at members of N - {r},

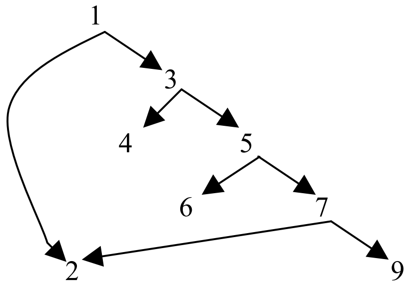
(iv Tree Parent Dominates Link Parent(s)) if $<n,n'> \in L$, then there are $m_0, \ldots, m_p \in N$ (p>0) such that $m_1 \neq n'$, $m_p = n$, $<m_0,n'> \in I$, and $<m_i,m_{i+1}> \in I$ whenever $0 \leq i < p$, for all $n, n' \in N$.

(v Node Labeling) $f(n) \in V_N$ iff there is an n' in N such that $<n,n'> \in I \cup L$ for all n in N.

Now, instead of treating all instances of immediate dominance alike, as is the case with ID within MC/MD-graphs, linked trees assign a unique designated "tree parent", $I^{-1}(n)$, to each node *n*, except for *r*. Thus, the surface- or Spell-Out position of *n* can be determined on the basis of this tree parent. In addition, traces are replaced by "links" in the sense that for each *m* that would have dominated a trace of *n* in a tree, $<m,n> \in L$ in a linked tree.

Let us have a look at the following simple example.

(44)

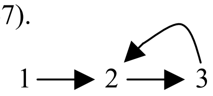


Instead of a single ID relation, PLG takes (44) to be partitioned into I and L as follows.

(45) a. I = {<1,2>, <1,3>, <3,4>, <3,5>, <5,6>, <5,7>, <7,9>}
b. L = {<7,2>}

Now, condition (iv) imposes a restriction on linked trees, similar to the Connected Ancestor Condition (CAC). Thus, take n=7 and n'=2 in (44)/(45), i.e. $<7,2> \in L$. The tree parent of 2 is 1, i.e. m_0=1 and $<1,2> \in I$. Then there is a sequence of nodes from the tree parent m_0 (=1) to the link parent m_p (=n=7), where each successor is related to its predecessor in terms of I, i.e. $<m_i,m_{i+1}> \in I$. Such a sequence is minimally of length

2, i.e. $p>0$. Thus, tree parent and link parent cannot be identical.[19] The constraint that $m_1 \neq n'$, i.e. that the I-path from tree parent to link parent must not go via their common child, together with condition (iii) guarantees the acyclicity of the resulting graph.[20] In (44) this is redundant. Assume $m_1=2$. Then $<2,7> \in I$ must hold, which violates the uniqueness condition (iii), given that $<5,7> \in I$ too. However, consider the graph in (46)/(47).

(46) 

(47) a. $I = \{<1,2>, <2,3>\}$
b. $L = \{<3,2>\}$

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[19] Technically, this means that linked trees are not "multigraphs," that is graphs allowing for the possibility of "several edges joining the same pair of vertices" (Trudeau 1993, p.24).

[20] A proof of acyclicity for linked trees would have to show that a) I^+ is irreflexive and b) adding links preserves irreflexivity, i.e. $(I \cup L)^+$ is irreflexive too (cf. the definition of MC/MD-graphs). The latter property may actually not hold, as shown in the following footnote. Here I give the outlines of a proof for a). Assume the definitions of proper lower and upper cone are transposed to I, i.e. we can use the same notation as before. We then have to establish (i).

(i) $\neg(\exists x \in N)[\ x \in \downarrow x\ ]$

Of course, (i) could be formulated differently, given the following equivalence.

(ii) $(\forall x \in N)[\ x \in \downarrow x \leftrightarrow x \in \uparrow x\ ]$

Let us now characterize a "loop" as a set of nodes in a graph where each node is a member of its own proper lower (and upper) cone and all members have identical lower and upper cones. This is what underlies the notion of "loop set" of x.

(iii) Loop Set

$\infty x =_{def} \{y \mid y \in \downarrow y \wedge \downarrow x = \downarrow y \wedge \uparrow x = \uparrow y\}$

It can be shown that a non-empty loop set of x must contain x itself, i.e. (iv) holds.

(iv) $(\forall x \in N)[\ \infty x \neq \varnothing \rightarrow x \in \infty x\ ]$

Likewise, if I is giving rise to a loop set ∞x, then every member of ∞x must be connected to at least one member of ∞x via I, i.e. (v) holds.

(v) $(\forall x,y \in N)[\ y \in \infty x \rightarrow (\exists z \in N)(\ z \in \infty x \wedge <z,y> \in I\ )\ ]$

Showing (i) then boils down to showing (vi), i.e. there are no loops.

(vi) $(\forall x \in N)[\ \infty x = \varnothing\ ]$

To show this one has to consider two cases: a) non-empty loops containing r, and b) non-empty loops excluding r. The former case is directly ruled out by the fact that if $r \in \infty x$ then $r \in \downarrow r$. This violates condition (iii) of (43), which takes $I^{-1}(r)$ to be undefined. Case b) is excluded because such a loop has to be connected to the root at some point, given condition (ii) of (43). However, the node which establishes contact to the root must violate uniqueness condition (iii) of (43), since it will be immediately dominated by a node outside of ∞x as well as by another one inside of ∞x, the latter due to (v). The state of affairs conflicting with condition (iii) of (43) is formally expressed in (vii).

(vii) $(\forall x \in N)[\ (\ \infty x \neq \varnothing \wedge r \notin \infty x\ ) \rightarrow$

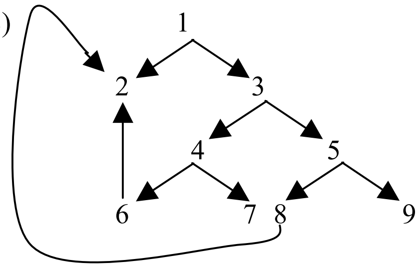
$(\exists w,y,z \in N)(\ w \in \uparrow x - \downarrow x \wedge \{y,z\} \subseteq \infty x \wedge <w,y> \in I \wedge <z,y> \in I\ )\ ]$

Here 3 does not have a second tree parent. This kind of cycle is directly ruled out by the condition that $m_1 \neq n'$, i.e. there must be a path from tree parent to link parent which does not go via the link child.[21]

Importantly, condition (iv) differs from the CAC in two main respects. First, it is assumed that the designated ("principal") tree position of each node is its "highest" position. If designated position and surface position are identified, this assumption has to be modified for minimalist syntax, where abstract (post Spell-Out) dependencies abound.[22]

Secondly, while each link parent must be dominated by the tree parent, link parents need not be ordered wrt each other in terms of I*. This makes PLG capable of capturing structures where one constituent seems to license two or more gaps, as is often assumed for ATB and parasitic gap constructions.[23] Thus consider (48)/(49).

(48)



(49) a. I = {<1,2>, <1,3>, <3,4>, <3,5>, <4,6>, <4,7>, <5,8>, <5,9>}
b. L = {<6,2>, <8,2>}

Condition (iv) is satisfied for both elements of L in (49b). Nothing more is required. Thus, neither $<6,8> \in I^*$ nor $<8,6> \in I^*$. The CAC, on the other hand, is violated by the graph in (48)/(49).[24]

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[21] By the same mechanism, all trivial links of type <x,x> where $x \neq r$ are ruled out. Finally, trying to make r a link child is prohibited by the fact that there would be no tree parent for the link child. This is in conflict with condition (iv) again. It seems, however, that cycles may arise if two (or more) links are added. Thus consider the following linked tree.
(i) a. I = {<1,2>,<1,3>,<2,4>,<2,5>,<3,6>,<3,7>} b. L = {<5,3>,<6,2>}
Node 3 is link child of a child of its sister 2, and, conversely, 2 is link child of a child of 3. The tree parent for both links is 1. The path from tree parent to link parent is <1,2,5> for link <5,3> and <1,3,6> for link <6,2>. Condition (iv) is fulfilled. Yet, a cycle has been created, comprising the set {2,5,3,6}. As a result $(I \cup L)^+$ of linked trees is not irreflexive, as opposed to ID^+ of (ordered) rooted MC/MD-graphs.

[22] It would be an interesting formal property of minimalist syntax if abstract movements were invariably carried out in a single step, i.e. if there were no successive-cyclic LF movement. Then the surface position of each constituent could be determined on the basis of λ by a very simple algorithm.

[23] For the latter see Engdahl (1986, p.129ff).

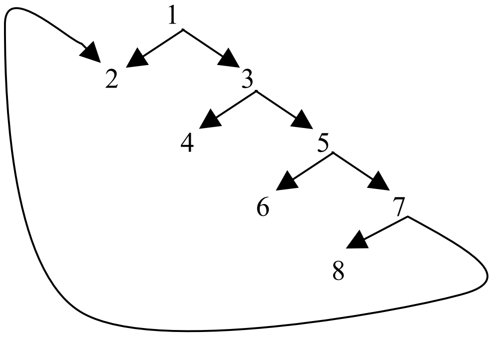
[24] It would have to be shown whether Barker&Pullum's (1990) results concerning formal command properties of acyclic graphs obeying the CAC carry over to linked trees.

Since the additional complexity of such multiple dependencies is beyond the immediate concerns of (narrow) minimalist syntax, the CAC will later be assumed to hold for the MC/MD-structures I introduce to simulate minimalist syntax.[25]

On the other hand, both condition (iv) and the CAC rule out dependencies that violate strictest c-command. We have seen that for the CAC above. Now assume we add link <8,6> to L of (48)/(49). There is no "descending" path from 4, the tree parent of 6, to 8, the link parent of 6, i.e. $<4,8> \notin I^*$. This violates condition (iv). Clearly, dependencies have to obey c-command within PLG. Thus, X°-movement as standardly construed cannot directly be captured in terms of linked trees either.

Let us now return to the issue of linear precedence. The approach based on the "Partial Exclusivity Condition" and the "Precedence Inheritance Condition" discussed above requires a strict ordering of *terminals*. This ordering can be projected onto non-terminals dominating continuous constituents. The PLG approach starts off with an ordering of each set of *siblings*, as stated in condition (i) on linked trees. Let us call the generalized union of these orderings "sibling precedence" (SP). Now consider the graph in (50), whose SP relation is given in (51).

(50)



(51) SP = {<2,3>, <4,5>, <6,7>, <8,2>}

Assume for convenience that the definitions of cones are transposed from ID to I and $I \cup L$, so that the same notation can be used in the following. Clearly, the equivalent of the Partial Exclusivity Condition on MC/MD-graphs does not hold for linked trees. $<2,3> \in SP$ and $<3,2> \in (I \cup L)^*$. Likewise the order of terminals is not unambiguously determined by (50)/(51). A simple recursive projection of (general) precedence like

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[25] Nunes (1995, 2001) analyzes parasitic gaps (and ATB constructions) in terms of "sideward movement." Crucially, as one of the derivable consequences of his system, the two gaps are not part of the same chain. There must be separate chains for each gap. Thus, the "anti-c-command" condition on parasitic gaps falls out as a consequence. While PLG requires separate "links" for distinct gaps as well, the anti-c-command condition would have to be stipulated, given that successive-cyclic movement will likewise be captured in terms of separate links. This time, however, one link parent will dominate the other. For further discussion of Nunes (1995), see Gärtner (1998).

(52), based on the Nontangling Condition on trees, is unsatisfactory because it does not (necessarily) result in a strict partial order.

(52) Precedence
a. $(\forall x,y \in N)[\ \langle x,y\rangle \in SP \rightarrow \langle x,y\rangle \in P\ ]$
b. $(\forall x,y,z,w \in N)[\ (\ \langle x,y\rangle \in P \wedge z \in \downarrow x \wedge w \in \downarrow y\ ) \rightarrow \langle z,w\rangle \in P\ ]$

For example, in (50)/(51) irreflexivity would be violated because $\langle 2,2\rangle \in P$ and asymmetry would be violated because both $\langle 2,4\rangle \in P$ and $\langle 4,2\rangle \in P$. However, PLG has a fairly simple way out.

> “The *language generated* by a phrase-linking grammar G is the set of yields (terminal strings) of trees that result by deleting all links from a linked tree admitted by G“ (Peters&Ritchie 1981, p.9).

Thus, for the purpose of linearization one can define a restricted ordering condition, which takes into account only “tree siblings.“

(53) Linear Precedence Ordering of Siblings
$P(n)$ is a strict linear ordering of $\{m|\ \langle n,m\rangle \in I\}$ for all n in N

The resulting generalized union called “tree sibling precedence“ (TSP) will be a subset of SP. Thus, since $\langle 7,2\rangle \in L$ of (50), TSP of (50) will be (54), i.e. $\langle 8,2\rangle \notin TSP$.

(54) $TSP = \{\langle 2,3\rangle, \langle 4,5\rangle, \langle 6,7\rangle\}$

Now (tree) precedence (TP) can be recursively projected as stated in (55), except that SP has to be replaced by TSP.[26]

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[26] Here lower cones are taken to be interpreted on the basis of just I. The actual PLG approach to “precedence projection“ is more complicated.

(i) A node m of a linked tree $\langle N,I,L,P,f\rangle$ is a *left-most descendent* of a node n in N if there are nodes $n'_1, \ldots, n'_p$ $(p\geq 1)$ such that $n = n'_1$, $n'_p = m$, $\langle n'_i, n'_{i+1}\rangle \in I\cup L$ for $1\leq i<p$, and for no $i=1, \ldots, p-1$ is there an n'' such that $\langle n'',n_{i+1}\rangle \in P(n_i)$.

The concept of *right-most descendent* is defined in an analogous way (cf. Peters&Ritchie 1981, p.7). On the basis of (i) the left and right edges of each constituent are captured. Then it is possible to define a notion of adjacency, which is called “immediate precedence.“

(ii) A node n of $\langle N,I,L,P,f\rangle$ *immediately precedes* a node m in N if there are n', m' and n_0 in N such that $\langle n_0,n'\rangle$ and $\langle n_0,m'\rangle$ are in $I\cup L$, n is a right-most descendent of n' and m is a left-most descendent of m', $\langle n',m'\rangle$ is in $P(n_0)$, and there is no n_1 such that $\langle n',n_1\rangle$ and $\langle n_1,m'\rangle$ are in $P(n_0)$ (Peters&Ritchie 1981, p.7f).

Although this adds further ordering for each graph, it does not for example establish any relation between nodes 4 and 6 in graph (50). Thus, while 6 is a left-most descendent of 5, 4 is not a right-most descendent of anything, given the irreflexivity of that notion. Thus although 4 and 6 would be candidates for “adjacency,“ this does not follow from (i) and (ii). In that sense the PLG system is still incomplete. A variant of this approach, originating with Blackburn&Meyer-Viol (1996), is

(55) Tree Precedence
a. $(\forall x,y \in N)[\, <x,y> \in TSP \rightarrow <x,y> \in TP\,]$
b. $(\forall x,y,z,w \in N)[\, (\, <x,y> \in TP \wedge z \in \downarrow x \wedge w \in \downarrow y\,) \rightarrow <z,w> \in TP\,]$

The resulting TP relation for the graph in (50) will be (56).

(56) $TP = \{<2,3>, <2,4>, <2,5>, <2,6>, <2,7>, <2,8>, <4,5>, <4,6>, <4,7>, <4,8>, <6,7>, <6,8>\}$

This unambiguously encodes the intended yield for (56), namely, 2+4+6+8. The PLG approach to linear precedence can thus be summarized by saying that the links of linked trees are just λ-relevant and not π-relevant.

Some such split is actually required in any system capturing (unbounded) dependencies in terms of multiple positions in graphs. Thus, standard movement approaches decide on π-relevance by realizing all but one position in a chain as phonologically null elements called "traces." If copies are employed instead, as is the case in minimalist sytax, as we have seen, there has to be a mechanism keeping track of the π-relevant copy within complex structures.[27]

I will come back to linear order in section 3.4.3 in the context of my own system, which coincides to a considerable degree with the PLG approach.

Further discussion of "arboreal" theories of MC/MD can be found in Blevins (1990), among them his own "Mobile Grammar," which we already mentioned. Although more emphasis is put on discontinuous constituents there, which are allowed in mobiles as well, MC/MD is empirically defended on the basis of data reminiscent of English *tough*-constructions (cf. section 2.5) found in Niuean, a language spoken in New Zealand.[28]

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proposed in Kracht (2001). There the ID relation for binary-branching graphs is partitioned into ID_1 and ID_2, such that $ID = ID_1 \cup ID_2$, where $<x,y> \in ID_1$ iff y is the *left* daughter of x and $<x,y> \in ID_2$ iff y is the *right* daughter of x. It is clear how to translate the earlier notion of "immediate precedence" into these terms.

(iii) A node n of $<N, ID_1,ID_2>$ *immediately precedes* a node m in N if there are n', m' and n_0 in N such that $<n_0,n'> \in ID_1$, $<n_0,m'> \in ID_2$, $<n',n> \in ID_2^*$, and $<m',m> \in ID_1^*$.

Note that for every x, $<x,x>$ ID_1^* and $<x,x>$ ID_2^*. On the basis of (iii) we can now say that in graph (50), interpreted as a binary MC/MD-graph in the sense of Kracht (2001), 4 "immediately precedes" 6.

[27] For proposals see Nunes (1995), Groat&O'Neil (1996), and Uriagereka (1997,1999).

[28] Blevins' radical conclusions wrt the nature of grammatical description raise issues of the kind indicated in section 1.1 above, which I prefer to sidestep. Consider the following quote: "Proposals for generating nonstandard representations are outlined at various points in this discussion, though it is assumed throughout that representational issues can be productively investigated independently of generation strategies. This assumption clearly conflicts with the standard generative practice of evaluating syntactic analyses in close conjunction with proposals for generating them. Nevertheless, if the central claims of this work are in the main correct, this would suggest that the generative emphasis on systems of rules and principles has substantially hindered rather than advanced the understanding of representational issues" (Blevins 1990, p.360).

3.2.1 Structure Sharing (An Excursus)

Let me now turn to another variety of MC/MD, namely, the one appealed to in “attribute-value“ based theories of grammar, often referred to as “value sharing,“ “structure sharing,“ or “reentrancy.“ This terminology points to a function-theoretic or graph-theoretic background, as will become clear momentarily. The common ground of these theories is their all-encompassing use of feature structures, associated with, or even directly incorporating, standard constituent structures. Informally speaking, feature structures pair up features and values, where values themselves can be (sets of) feature-value pairs. Thus the feature *agreement* in (57) is assigned a complex value consisting of the features *number* and *person*, the former having value *singular*, the latter *third*.

(57)
$$\left[\begin{array}{l} \text{agreement} = \left[\begin{array}{l} \text{number} = \text{singular} \\ \\ \text{person} = \text{third} \\ \text{b} \end{array}\right] \\ \text{a} \end{array}\right]$$

A concise definition is given by Johnson (1988, p.18) under the name of “attribute-value structures.“[29]

(58) An *Attribute-Value Structure* A is a triple A = <F,C,δ>, where F is a set, C is a subset of F, and δ is a partial function from F×F into F such that δ(c,f) is undefined for all c ∈ C and f ∈ F. The set F is called the set of *Attribute-Value Elements* of A, and the set C is called the set of *Constant Elements* of A. The class of attribute-value structures is called AVS.

On this view, the representation in (57), called an “attribute-value matrix“ (AVM), corresponds to the attribute-value structure in (59).

(59) a. F = {agreement, number, person, singular, third, a, b}
b. C = F-{a,b}
c. δ(a,agreement) = b, δ(b,number) = singular, δ(b,person) = third

Note the use of arbitrary names for complex attribute-value elements. Clearly, the appeal to *δ* as a function opens up the possibility of “value sharing.“ Thus, imagine we add a complex element *c* to the structure in (57). Nothing then prohibits the addition of *δ(c,agreement)=b* to (57c), which amounts to saying that *a* and *c* coincide wrt the value of their agreement attributes. The corresponding AVM captures value-sharing in terms of coindexation, as shown in (60).[30]

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[29] Johnson abstracts away from particular linguistic frameworks. As already indicated earlier, an introduction into GPSG, HPSG, and LFG can be found in Abeillé (1993). For detailed exposition and analyses see Gazdar et al. (1985), Pollard&Sag (1987, 1994), and Bresnan (ed.) (1982).

[30] See Shieber (1986) for discussion of various notations.

(60)
$$\left[\begin{array}{l} p = \left[\begin{array}{l} \text{agreement} = \textcircled{1}\left[\begin{array}{l}\text{number} = \text{singular}\\ \text{person} = \text{third}\end{array}\right]_{b} \end{array}\right]_{a} \\ q = \left[\begin{array}{l}\text{agreement} = \textcircled{1}\end{array}\right]_{c}\end{array}\right]_{e}$$

(60) involves a case of "token identity." There is exactly one *3rd person singular* entity. For linguistic purposes it is important to also allow for "type identical" "occurrences" of linguistic elements , i.e. elements that happen to coincide in their featural make-up (cf. section 2.6.1). Consider (61).

(61)
$$\left[\begin{array}{l} p = \left[\begin{array}{l} \text{agreement} = \left[\begin{array}{l}\text{number} = \text{singular}\\ \text{person} = \text{third}\end{array}\right]_{b} \end{array}\right]_{a} \\ q = \left[\begin{array}{l} \text{agreement} = \left[\begin{array}{l}\text{number} = \text{singular}\\ \text{person} = \text{third}\end{array}\right]_{d} \end{array}\right]_{c}\end{array}\right]_{e}$$

(60) differs from (61) in that the values of *δ(a,agreement)* and *δ(c,agreement)* are *type*-identical in the latter and *token*-identical in the former. The use of two arbitrarily named attribute-value elements as opposed to coindexation guarantees that difference. Suppose, however, that complex elements were just sets of attribute-value pairs. Then, given extensionality of set theory, *b* and *d* would be identical, as shown in (62) (cf. Carpenter 1992, p.125).

(62) a. b = {<number,singular>,<person,third>}
b. d = {<number,singular>,<person,third>}

As a result, the structures in (60) and (61) would become identical, representable by the set in (63).

(63) {<p,{<agreement,{<number,singular>, <person,third>}>}>,
<q,{<agreement,{<number,singular>, <person,third>}>}>}

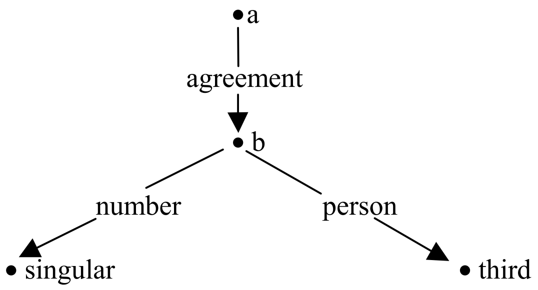
That the function-theoretic approach may not be the most perspicuous way of dealing with type identity vs. token identity is pointed out by Johnson (1988, p.22).

> "Note that according to the definition of attribute-value structures given above, each constant element appears only once in an attribute-value structure. This means that in fact there is much more 'value sharing' in the actual attribute-value structure than is indicated in the depictions shown above."

This result is again due to extensionality. There are no "copies," which means that the notations are potentially misleading.[31]

The linguistically more familiar way of looking at feature structures is *graph-theoretic*. Thus, the "usual way to conceptualize a feature structure is as a labeled rooted directed graph" (Carpenter 1992, p.36; cf. Shieber 1986, p.20). The AVM in (57) can be translated into the graph in (64).

(64)



Here, each node (reflexively) "dominates" a feature structure. It is important to note that not only nodes but also edges are labeled. In that respect, features structures by far exceed representation of the ID-relation. Take the following definition by Carpenter (1992, p.36).

(65) A *feature structure* over TYPE and FEAT is a tuple $F = \langle Q,q',\theta,\delta\rangle$, where:
Q: a finite set of *nodes* rooted at q'
$q' \in Q$: the *root* node
$\theta: Q \rightarrow$ TYPE: a total node *typing* function
δ: FEAT$\times Q \rightarrow Q$: a partial *feature value* function
let $\mathbb{F}$ denote the collection of feature structures.

For our purposes we can ignore the difference between types and features underlying the sets TYPE and FEAT.[32] Now, structure sharing arises from relaxing the Single

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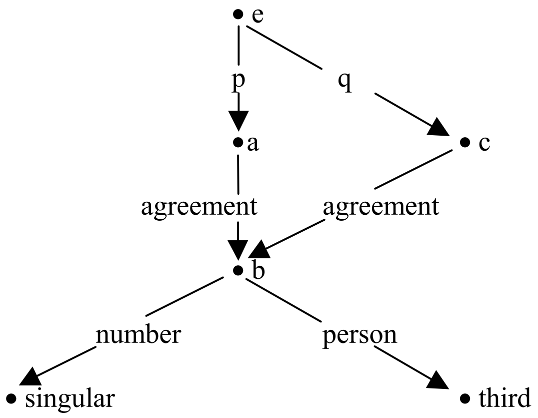
[31] This question will recur in section 3.3.2 below.

Mother Condition, (8) above, a possibility freely available, given that we are not dealing with trees. Thus, (60) would receive the minimally different representation in (66).[33]

(66)



With this rudimentary understanding of structure sharing, we can turn to some linguistic analyses couched in such terms. The question, of course, arises whether any *theoretical* claims hinge on the use of structure sharing or whether we are merely dealing with a *convenient* linguistic tool (cf. Shieber 1986, chapter 4). Pollard&Sag (1994, p.19) have been very clear on this.

> "It is not going too far to say that in HPSG structure sharing is the central explanatory mechanism, much as move-α is the central explanatory mechanism in GB theory; indeed the relationships between fillers and traces, between 'understood' subjects and their controllers, between pronouns and their antecedents, between 'agreement sources' and 'agreement targets,' and between the category of a word and the category of its phrasal projections will all be analyzed as instances of structure sharing."

For our narrowly minimalist purposes, we can concentrate on the treatment of movement dependencies in attribute-value systems. Consider first a (simplified) LFG-analysis of raising, as discussed in Johnson (1988). In Chomskyan generative syntax, raising is taken to be an instance of A-movement, leaving a trace, as in (67a). LFG, on

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[32] As indicated by Pollard&Sag (1987, p.27), there is a close formal connection between feature structures and "finite state automata." Thus, Q corresponds to the set of "states" and δ to the "transition function" (cf. Partee et al. 1993, chapter 17).

[33] Feature structures are often required to be acyclic (Shieber 1986, p.20). For formal discussion of how to add this property, see Johnson (1988, p.50ff) and Carpenter (1992, chapter 5). Note also that "[i]n terms of implementation, it turns out to be more expensive to eliminate cycles than to allow them" (Carpenter 1992, p.35).

the other hand, takes the subject NP to be base-generated in its surface position, as shown in (67b).

(67) a. [$_{IP}$ Mary$_i$ seems [$_{IP}$ t_i to sleep]]
b. [$_S$ [$_{NP}$ Mary] [$_{VP}$ seems [$_{VP}$ to sleep]]]

Thus, as far as "c-(onstituent) structure" goes, LFG recognizes only one constituent, *[$_{NP}$ Mary]*, unambiguously immediately dominated by S. The semantically relevant information that Mary is the argument of *to sleep* is encoded in terms of so called "f-(unctional) structure." The f-structure associated with (67b) is given in (68).[34]

(68)

$$\left(\begin{array}{l} \text{subj} = {}_{\textcircled{1}}\left[\begin{array}{l} \text{agr} = \left[\begin{array}{l}\text{pers} = \text{3rd}\\ \text{num} = \text{sg}\end{array}\right] \\ \text{pred} = \text{Mary}\end{array}\right] \\ \text{comp} = \left[\begin{array}{l}\text{subj} = \textcircled{1} \\ \text{pred} = \text{sleep}\end{array}\right] \\ \text{pred} = \text{seem}\end{array}\right)$$

Value-sharing, indicated by coindexation, guarantees that the feature structure associated with the NP *Mary* assumes the subject function for both S and the minimal VP. Clearly, this analysis presupposes the LFG-approach to grammatical functions, which takes them to be primitives of the theory represented at the level of f-structure. This additional representation lends more flexibility to the use of structure-sharing beyond the modeling of movement chains.

Let us turn to A'-movement next. This time we'll focus on a simplified HPSG analysis.[35] HPSG has fully integrated constituent structures into feature structures, encoding the ID-relation in terms of the attribute DTRS ("daughters"). Combining this

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[34] Adapted from Johnson (1988, p.17). Pollard&Sag (1994, p.4) likewise assume that "[. . .] there is no need to posit an actual constituent [. . .]" in the case of raising.

[35] For an LFG analysis of unbounded dependencies in terms of f-structures, see Kaplan&Zaenen (1989). There, an extracted element is assigned its grammatical function by means of a "path equation" like (i) (Kaplan&Zaenen 1989, p.27).
(i) (↑ TOPIC) = (↑ COMP* OBJ)
This roughly says about a fronted ("topicalized") constituent that its GF, OBJ, can be found embedded within an arbitrary number of complements. Unboundedness is thus guaranteed by Kleene closure (*).

kind of attribute with the mechanism of structure sharing, one could translate an MC/MD-graph like the one in (32) above into the AVM below.[36]

(69)
$$\left(\begin{array}{ll} \text{F-DTR} = {}_{\text{①}}2 & \\ \text{S-DTR} = & \left(\begin{array}{ll} \text{F-DTR} = 4 & \\ \text{S-DTR} = & \left(\begin{array}{l} \text{F-DTR} = \text{①} \\ \text{S-DTR} = 7 \\ 5 \end{array}\right) \\ 3 & \end{array}\right) \\ 1 & \end{array}\right)$$

However, the relation between F-DTR of 1 and F-DTR of 5 is a "nonlocal" relationship. While this is typical for the output of operations like move-α, it is off-limits for the transformation-less approach pursued by HPSG. Thus, the relation is broken down into a series of local licensing steps. For this purpose, each intermediate projection is provided with an attribute SLASH, linking the positions of the dependency by means of some additional structure sharing. The required additions to (69) are given in rough form in (70).

(70)
$$\left(\begin{array}{ll} \text{SLASH} = \varnothing & \\ \text{F-DTR} = {}_{\text{①}}2 & \\ \text{S-DTR} = & \left(\begin{array}{ll} \text{SLASH} = \{\text{①}\} & \\ \text{F-DTR} = 4 & \\ \text{S-DTR} = & \left(\begin{array}{l} \text{SLASH} = \{\text{①}\} \\ \text{F-DTR} = \text{①} \\ \text{S-DTR} = 7 \\ 5 \end{array}\right) \\ 3 & \end{array}\right) \\ 1 & \end{array}\right)$$

Well-formedness conditions can now be imposed locally by means of ID-schemata, much in the spirit of the original context-free phrase structure rules of GPSG (Gazdar et al. 1985), which replace move-α.[37] Of course, given the property of structure sharing,

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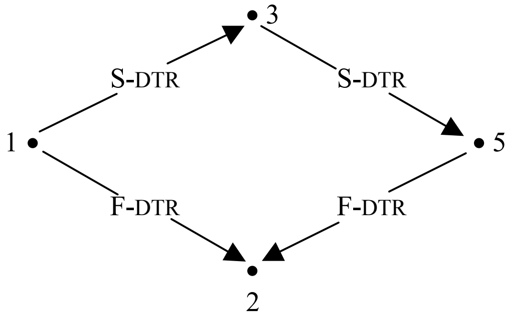
[36] For expository purposes, I use binary branching structures, where F-DTR and S-DTR stand for "first" and "second" daughter respectively. See Blackburn&Meyer-Viol (1996) for such an approach to graphs. As is well known, GPSG and HPSG advocate the separation of ID and LP relations, i.e. ID schemata do not impose any linear ordering on constituents.

[37] SLASH is set-valued in order to allow multiple extraction. If lists are used instead, constraints like "nestedness" can be implemented by imposing stacking conditions like "first-in-last-out" (cf.

which, as we already established, involves token identity, it is less clear what “locality“ really means from a representational perspective. Consider the graph in (71), which translates the essential relations from (70).

(71)



There is no general formal requirement that structure sharing nodes be adjacent in the resulting graph.[38] Rather, the SLASH-mechanism seems to be a special device for dealing with unbounded dependencies in a linguistically satisfactory way. In fact, the amount of structure sharing alotted to A'-dependencies in HPSG is less than what I made it look like so far. Instead of sharing full-fledged constituents, dependencies are formed only wrt “local features,“ i.e. formal features like *category* and *Case*, as well as semantic features. Phonological features, for one thing, are only available at the surface position. Thus, dependencies involve two constituents, namely, a “filler“ and a trace (a.k.a. “gap“), which coincide wrt local features. Structure sharing is pushed to the sub-constituent level.[39] Technically, traces look roughly as follows.

(72)
PHON = < >
LOCAL = ①
SLASH = {①}

These entities introduce a phonologically empty constituent whose local features are in need of identification with those of the filler, which are to be found somewhere along the projection path of the SLASH-feature. In addition, these features can be constrained

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Pollard&Sag (1994, p.169fn.9). The formal background for the SLASH mechanism is provided by “indexed grammars“ (Partee et al. 1993, p.534ff; Wartena 2000). Note also the close formal connection between SLASH-feature percolation, the Connected Ancestor Condition on MC/MD-graphs and the C-command Condition on Move.

[38] See Pollard&Sag‘s (1994, p.17) analysis of the pronoun *she*, where such a putative requirement would have been violated.

[39] Compare this approach to the idea that feature-movement is more fundamental than constituent movement advocated in Chomsky (1995a, chapter 4). See also section 2.7.4 above.

by the local syntactic context in terms of subcategorization by a head. By way of an example, (73) and (74) provide a rough analysis of topicalization.

(73) $[_S$ Kim$_i$ $[_S$ Dana $[_{VP}$ hates t_i]]]

(74)
```
( PHON = <Kim,Dana,hates>
  SLASH = ∅
  LOCAL = ( F-DTR = [ PHON = <Kim>
                      SLASH = ∅
                      LOCAL =  [ CAT = NP
                              ①[ CASE = Acc ] ]
            S-DTR = ( PHON = <Dana,hates>
                      SLASH = {①}
                      LOCAL = ( F-DTR = [ PHON = <Dana>
                                          SLASH = ∅
                                          LOCAL = [ CAT = NP
                                                    CASE = Nom ] ]
                                S-DTR = ( PHON = <hates>
                                          SLASH = {①}
                                          LOCAL = ( F-DTR = [ PHON = <hates>
                                                              SLASH = ∅
                                                              LOCAL = CAT = V ]
                                                    S-DTR = [ PHON = <>
                                                              SLASH = {①}
                                                              LOCAL = ① ] ) ) ) ) ) )
```

Pollard&Sag (1994, section 9.5) and Sag&Fodor (1994) discuss a traceless alternative to this kind of analysis. Accordingly, no node or terminal at all is used in the position of the gap. Instead, for complement extraction the selecting head is modified by a lexical rule to the effect that the SLASH-feature will be introduced by that head directly. The usual subcategorization constraints can be put on the value of the SLASH-feature inside that lexical item.[40]

Close attention to further technical detail of such rival approaches would, of course, be useful in analyzing minimalist syntax, potentially yielding answers to the questions discussed in section 1.1.[41] However, in compliance with the hypotheses developed in

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[40] Subject- and adjunct extraction require additional refinements, discussion of which would carry us too far afield (See Pollard&Sag 1994, section 9.5).

[41] Thus, there may be further "lower" levels of implementation to be taken into account. John Frampton (p.c) has directed my attention to the interpretation of links as "pointers," common in computer science. Implementation of pointers usually requires highly structured objects, located at an address and comprising a "content field" at which some information can be stored as well as "pointer fields" that contain the addresses of further objects of the same kind (cf. Cormen et al. 1990, p.209-213, and Karttunen&Kay 1986). The idea of addressing will show up later in section 3.3.3 as an ingredient of implementing MC/MD in minimalist syntax. Note, incidentally, that

section 2, my foremost task is to show how MC/MD can be added to minimalist syntax and at what cost. Suffice it to say here that there are close links between my proposal and the HPSG approach to (unbounded) dependencies on the basis of structure sharing. To the extent that I'm successful, I will be able to rely on a number of arguments developed within HPSG in defending the use of MC/MD instead of traces or copies.[42]

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developing parsing techniques on the basis of copying and “unification“ operations, Karttunen& Kay (1986) come to the conclusion that “the amount of computational effort that goes into producing these copies is much greater than the cost of unification itself“ (Karttunen&Kay 1986, p.6). Thus, in order to save effort they propose to “minimize copying by allowing graphs share common parts of their structure“ (Karttunen&Kay 1986, p.7). Similar views are expressed by Pereira (1986). For another complexity result for copying, see Rogers (1998). If what I have tried to indicate in section 1.1 is along the right track, namely, that memory expenditure of grammar implementations might have an impact on how “perfect“ language is, claims like the ones above might have some importance. Again, I refrain from further speculation here.

[42] Cf. Sag&Fodor (1994).

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