

# Flexible Composition, Multiple Adjoining and Word Order Variation

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## Abstract

Tree-Local Multi-Component TAGs (called hereafter just MC-TAG for short) are known to be weakly equivalent to standard TAGs, however, they can describe structures not derivable in the standard TAG. There are other variants of MC-TAG, such as MC-TAG with (a) flexible composition and (b) multiple adjoining of modifier (non-predicative) auxiliary trees that are also weakly equivalent to TAGs, but can describe structures not derivable with MC-TAG. Our main goal in this paper is to determine the word order patterns that can be generated in these MC-TAG variants while respecting semantic dependencies in the grammar and derivation. We use some word order phenomena such as scrambling and clitic climbing to illustrate our approach. This is not a study of scrambling or clitic climbing per se. We do not claim that the patterns of dependencies that are derivable are all equally acceptable. Other considerations such as processing will also come into play. However, patterns that are not derivable are predicted to be clearly unacceptable.

## 1 Introduction

This paper examines the different word orders that can be generated while maintaining the same word to word dependencies using several extensions of tree-local Multi-Component TAG (MC-TAG). We find that when the system is enriched to allow *flexible composition*, not all patterns can

be derived beyond two levels of embedding. Flexible composition is the mirror operation to adjoining; if tree  $\alpha$  adjoins into tree  $\beta$ , the combination can be alternatively viewed as tree  $\beta$  “flexibly” composing with tree  $\alpha$  (Joshi et al. 2003, Kallmeyer and Joshi 2003). By enriching MC-TAG with this perspective of adjoining, some derivational steps which appear to permit components from the same MC-set to combine into different trees can be recast as abiding by tree-locality. Tree-local MC-TAGs with flexible composition have been investigated from the point of view of understanding the range of structures they can generate. Some of the phenomena where flexible composition has been useful include scope ambiguity and available readings in nested quantifications (Joshi et al. 2003, Kallmeyer and Joshi 2003), complex noun phrases in pied-piping and stranding of wh-phrases (Kallmeyer and Scheffler 2004), and binding (Ryant and Scheffler 2006). The full range of flexibility that can be allowed without going outside the weak generative capacity of standard LTAG is not known yet. In this paper, the flexible composition we explore is limited to reverse adjoining at the root.

Our investigation also includes a look at the effects of enforcing binary branching. The TAG composition operations, substitution and adjoining are binary, in the sense that each operation involves composing two trees into one, two structures into one. However, there is another dimension for this issue of binarization in TAG which does not arise in other systems, such as CFGs or Categorical Grammars, for example, as these are essentially string rewriting systems. In the case of TAG, we have a choice at the level of the elementary trees. We can require all elemen-

tary trees to be binary or we can allow some elementary trees to be non-binary. We find that binarizing the elementary trees results in additional nodes (in comparison to its non-binarized counterpart), allowing additional patterns to be derived in MC-TAG with flexible composition.<sup>1</sup>

Most of this paper is devoted to illustrating our approach using scrambling in German. We assume a single set of linguistic dependencies, and we consider the possible word orders when the dependencies are respected throughout the derivation. Lastly, we take a preliminary look at clitic climbing under the same approach.

## 2 German Scrambling

In subordinate clauses in Standard German, the canonical order of verbs and their subject arguments is a nested dependency order. However, other orderings are also possible. For example, in the case of a clause-final cluster of three verbs, the canonical order is as given in (1),  $NP_1 NP_2 NP_3 V_3 V_2 V_1$ , but all other permutations of the NP arguments are also possible orderings.<sup>2</sup>

- (1)  $NP_1 NP_2 NP_3 V_3 V_2 V_1$   
 . . . Hans Peter Marie schwimmen lassen sah.  
 . . . Hans Peter Marie swim make saw  
 “. . . Hans saw Peter make Marie swim.”

However, with an additional level of embedding, i.e. four NPs and four verbs, the situation is less clear both linguistically and formally. Some orderings, such as (2), are consistently taken to be (more) acceptable, while others, such as (3) are consistently dispreferred.

- (2)  $NP_4 NP_1 NP_2 NP_3 V_4 V_3 V_2 V_1$   
 (3)  $NP_3 NP_1 NP_4 NP_2 V_4 V_3 V_2 V_1$

Interestingly, just as natural language appears not to permit all permutations of nouns at this deeper level of embedding, so too does tree-local MC-LTAG allow only certain permutations. (Becker

et al., 1991, Rambow 1994, Joshi et al., 2000). Here, we closely examine the situation involving three levels of embedding. Twenty four orderings result from permuting the four nouns while keeping the verb order fixed.<sup>3</sup> Our focus is on making the formal predictions of a system that allows flexible composition precise. The linguistic dependencies we assume here are (a) that between a verb and its NP argument and (b) that between a verb and its VP argument. The former is respected by the standard TAG approach to verbs and their arguments: the set anchored by  $V_i$  includes a substitution node for  $NP_i$ . The latter is respected both by having a  $VP_{i+1}$  node in the set anchored by  $V_i$  as well as requiring the VP argument of  $V_i$  to be  $V_{i+1}$  throughout the derivation.<sup>4</sup> For example, tree sets for  $V_1$  and  $V_3$  can only combine with one another if one of them has combined with  $V_2$  first. The task at hand is to see which variants of MC-LTAG derive which permutations, setting the stage to compare whether the sequences that require more powerful extensions align with dispreferred sequences.

## 3 Tree-Local MC-TAG Extensions

We take tree-local MC-LTAG as our starting point: all components belonging to the same MC-set must combine into a single elementary tree. In the linguistic context, there is always a constraint between the two components of an elementary tree set of an MC-TAG. Usually, there is an implied “top” and “bottom” tree, and we require the foot node of the top tree to dominate (but not immediately) the root node of the bottom tree. Using Grammar 1 in Figure 1 as an example, this means that the  $N_i$  component must be above the  $V_i$  predicative component in the derived phrase structure. The constraint can also be a c-command relation. In any case, the constraint does not permit the immediate domination of the root node of the bottom tree by the foot node of the top tree. There would be no point of having a two component tree if this were to be the case.

An outcome of prohibiting immediate domination between the two components is that each

<sup>1</sup> Conversely, when binarization eliminates nodes, e.g. binarizing a grammar that allowed nodes with a single non-terminal daughter, binarization is expected to decrease the possible derivations.

<sup>2</sup> Some permutations sound better with full NPs instead of proper names. Examples can be found in (Rambow 1994). Our purpose here is just to illustrate possible patterns.

<sup>3</sup> There are other patterns of scrambling, for example,  $N_1 N_2 N_3 V_1 V_3 V_2$ , involving permutations of  $V$ 's. We do consider these here for now.

<sup>4</sup> I.e. We adopt the strong co-occurrence constraint of Joshi et al (2000).

component must target two distinct nodes for the composition to be valid. If both components were to target the same node, the non-immediate domination constraint would be violated. This kind of composition is ill-defined for MC-TAG.

### 3.1 Permitting Flexible-composition

We first investigate the effect of allowing flexible composition, but only when adjoining would have taken place at a root. We do not consider reverse adjoining at internal nodes. Thus, if tree A flexibly composes into tree B, then it is the reverse of B adjoining into A's root.

Under this extension, we also do not allow flexible-composition at a node that also serves as a target for adjoining. For example, this prohibits the derivational steps in Figure 1: A and B are auxiliary trees with the same root and foot node labels. B adjoins into the root of C, and C flexibly composes at its root with A. If we take the notion of flexible-composition as “reverse adjoining” seriously, then allowing flexible-composition and adjoining at the same node would be multiple adjoining in disguise. In our example, the derivation shown is the same as adjoining both A and B into the root node of C. Some cases of flexible-composition and adjoining at the same node will be permitted under the multiple adjoining extension described below.

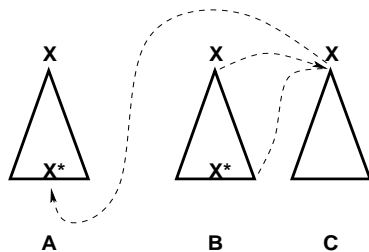


Figure 1: Flexible composition and adjoining at the same node. This is prohibited in TAG extensions without multiple adjoining.

### 3.2 Permitting Multiple-adjoining

What we mean by *multiple adjoining* is the Schabes and Shieber (1994) style multiple adjoining extended to apply to MC-sets: more than one component tree may adjoin into a host node so long as at most one of those trees is a predicative tree.<sup>5</sup> We follow Schabes and Shieber (1994)

<sup>5</sup> We treat the nouns as a type of modifier of the verb. I.e., we allow the following to adjoin into a single node: a mul-

in assuming that although either one of the multiply-adjoined structures may be on top (i.e. one derivation tree may correspond to more than one phrase structure), the order of the elementary trees in the final derived tree is determined by the order of adjoining: if tree A adjoins into a node X before tree B adjoins into the same node X, then tree A will be below tree B in the derived tree.<sup>6</sup> Additionally, we require that trees that target the same node belong to different MC-sets.

## 4 Non-binarized Phrase Structure

The grammar we first explore is shown in Figure 2. These tree sets are based on the tree-sets for a verb with two arguments given in Becker et al, (1991) which have been assumed for subsequent TAG approaches to German scrambling. A point of departure, however, is that these trees have more than one VP node. While we assume that the VP nodes belonging to the noun components do not carry the indexing information for the verb it is associated with, we do assume that both the root VP node and internal VP nodes, if any, of a predicative elementary tree carry the indexing information associated with the verb. This means that there is an additional potential “host” node for adjoining, and hence, each scrambled sequence may have more than one structural description. For example, consider the singleton sets in Grammar 1 for  $V_1$  and  $V_2$ . The  $V_1$  tree may adjoin into either the root node or the internal VP node of the  $V_2$  tree and maintain semantic coherence. In contrast, we also assume that the noun components in Grammar 1 do not have host nodes for predicates. This has the effect of banning adjoining into the noun components in general: an  $NP_i$  component cannot combine into an  $NP_j$  component without leaving the predicate  $V_i$

multiple noun components, or b) any number of noun components and one verb component. Since we have a different notion of modifier and predicate, we diverge from Schabes and Shieber (1994) by assuming predicative trees appear below modifier trees.

<sup>6</sup> Multiple-adjoining is related to tree-local MCTAG with shared nodes (SN-MCTAG) (Kallmeyer, 2005) in that a node which hosts adjoining is not seen as having disappeared in the tree-rewriting process. Rather, the host node and the root node of the tree being adjoined are identified, and the node is considered to belong to both trees. Thus, the targeted node is still available as a host for additional adjoining. SN-MCTAG also considers the foot node to have identified with the host node and to be available as a host for additional adjoining, unlike Schabes and Shieber (1994).

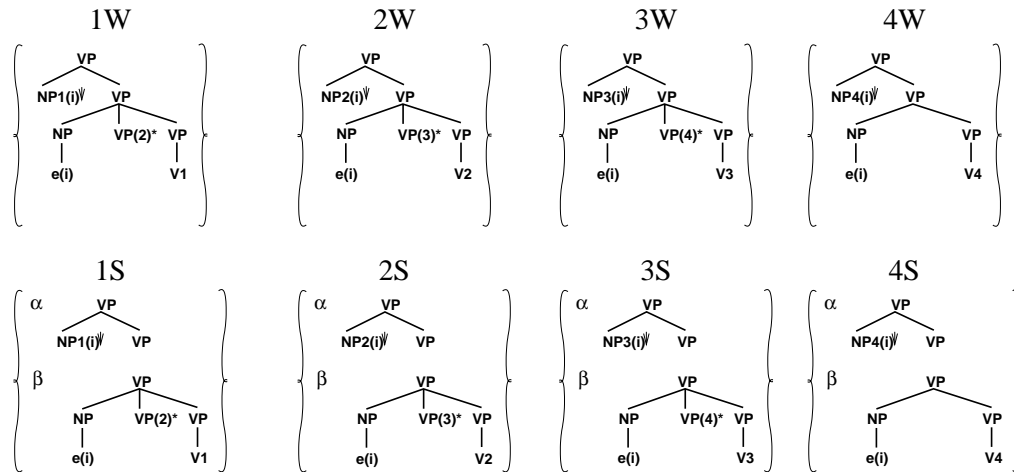


Figure 2: Scrambling Grammar 1. Each verb anchors a singleton set and a set with a two components

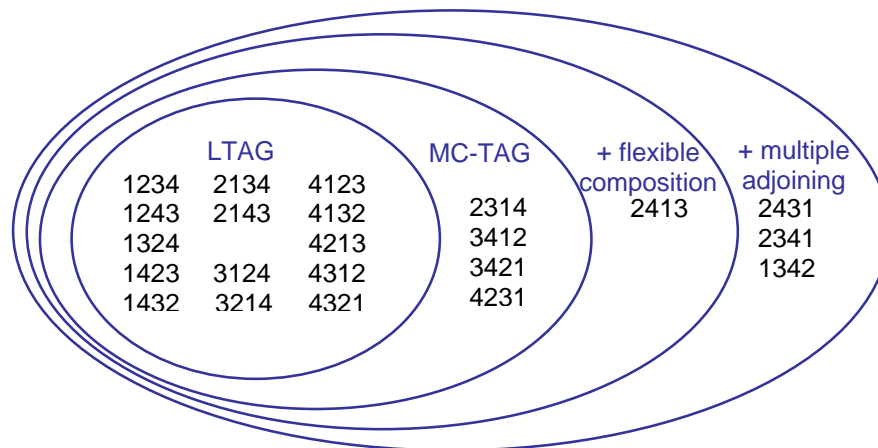


Figure 3: Derivable sequences given Grammar 1. MC-TAG with flexible composition derives structures for 15 permutations. Allowing multiple adjoining as well derives 22 permutations. The remaining 2 permutations require composition that is essentially ternary.

component without a host to combine into. Figure 3 shows which sequences are derivable under which TAG extensions.<sup>7</sup> Since we hold the sequence of verbs fixed, we use a number sequence to refer to the order of the NPs. E.g. We use 1234 as shorthand for  $NP_1NP_2NP_3NP_4V_4V_3V_2V_1$ .

Given Grammar 1, fourteen sequences are derivable with LTAG (i.e. using only the singleton sets in Grammar 1), and four additional sequences are derivable with MC-LTAG. Since deriving one of the noun sequences in the case of three noun-verb pairs, 231, already requires MC-TAG, this is no surprise.

For this particular grammar, only one additional sequence is derivable as the result of extending MC-LTAG to include flexible composition. Since each tree has at most three host VPs, there is no tree in Grammar 1 into which two MC-sets can combine. Since a tree from Grammar 1 only hosts at most one MC-set, many derivations involving flexible composition can be recast using classic adjoining. Additionally, because the singleton sets' trees include more than one host VP for a higher verb, more than one semantically coherent derivation are actually available for some sequences, even in LTAG.

When the system allows multiple-adjoining, three more sequences become derivable. Consider the derivation for 2341 in Figure 4. Flexible composition allows the singleton set anchored by

<sup>7</sup> Note that not all of the subset relationships in Figure 3 and Figure 6 are obligatory. E.g. It is possible to allow multiple adjoining without allowing multi-component sets.

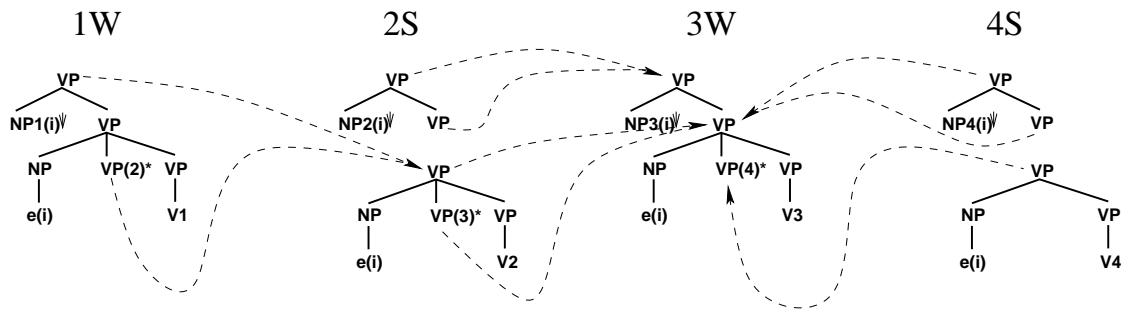


Figure 4: Derivation for 2341. Multiple-adjoining allows the upper components from 4S to target the internal VP node of 3W after 2S has already adjoined into the same node. Flexible composition allows the predicate component of 4S to combine into the foot node of 3W.

$V_3$  to be the root-tree of the derivation (i.e. the root in the derivation structure) even though it is an auxiliary tree. The MC-set anchored by  $V_4$  and that anchored by  $V_2$  both combine into  $V_3$ . One component from each set targets the internal VP node in  $V_3$ 's tree.

Two sequences remain underivable: 3142 and 3241. We also explore what kind of modification is needed to derive these sequences. We find that a type of adjoining that appears effectively to be a ternary operation is capable of doing so, and we conjecture that deriving these sequences require some sort of ternary composition. We refer to this “ternary” operation as *same-set multiple adjoining*: components belonging to the same MC-set are permitted to adjoin into the same host node. The difference between adjoining a “whole tree” into a single node and adjoining two components of the same set into a single node is that a non-predicative component from a different set is permitted to also adjoin into the same node. E.g. Given Grammar 1, an NP component associated with  $V_2$  can separate the top and bottom components of the set anchored by  $V_3$  when all three components adjoin into the same node. Note, however, that if we abide by the Schabes and Shieber (1994) convention that order of adjoining determines the order of the trees that adjoin into the same node, then the ordering  $NP_3NP_2V_3$  requires that the predicate component of the  $V_3$  set adjoin first, the  $NP_2$  component of the  $V_2$  set to adjoin next, and the  $NP_3$  component of the  $V_3$  set to adjoin in last. This application of same-set multiple adjoining needs access to three MC-sets: the host tree, the  $V_3$  set, and the  $V_2$  set.

Note that the need for same-set multiple adjoining to derive structures for these sequences is

an observation about a formal system, not an argument that this system is needed to adequately model natural language. It is not clear that these scrambling sequences are actually accepted by German speakers. Thus, unlike flexible composition and the Schabes and Shieber (1994) style multiple adjoining, same-set multiple adjoining has not been linguistically motivated.

## 5 Binarized Phrase-structure

Though Grammar 1 is empirically motivated, the tree structures lack a characteristic that has been assumed of phrase structures since the mid-eighties: these trees are not binary branching. Binary branching has been assumed for reasons such as linearizability (as in Kayne 1994) and as the result of the generative machinery. In many formalisms (e.g. combinatory categorical grammar (Steedman 1996), minimalist grammar (Stabler 1997), binary composition and binary branching are collapsed. In the TAG formalism, however, binary composition and binary branching can be separated. That is, the derivation is distinct from the derived phrase structure. Though the TAG operations are binary, the trees that they combine are not necessarily binary branching. Note, though, that enforcing binary branching phrase structure can easily be stated in TAG by requiring the kernel trees to be binary branching. Because TAG allows us to separate binary branching from binary composition, we can more clearly see the contribution of each by examining possible derivations in the case where binary branching is enforced vs. the case where binary branching is not enforced. The second grammar we consider is the binarized counterpart to the first grammar. This is shown in Figure 5.

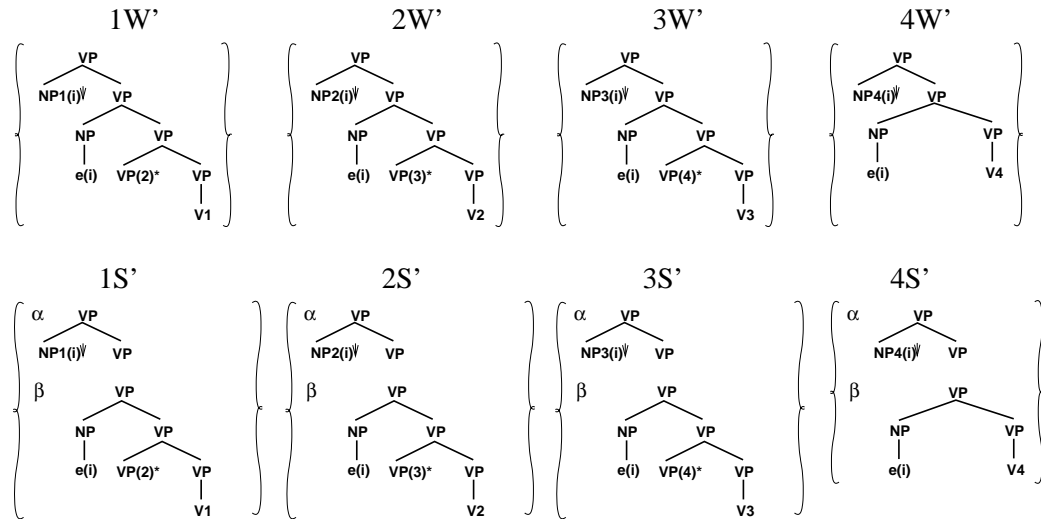


Figure 5: Scrambling Grammar 2. The binarized counterpart to Grammar 1

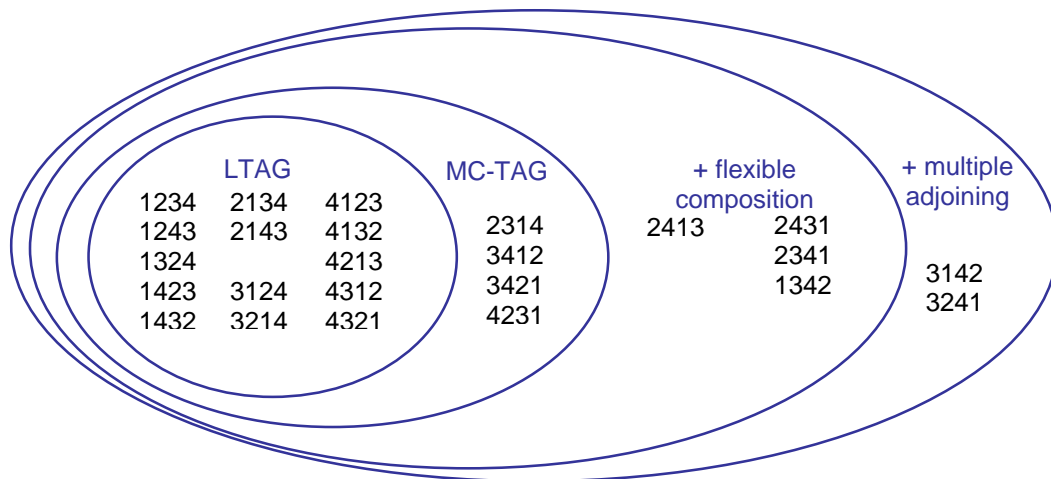


Figure 6: Derivable sequences given Grammar 2. Sequences which required multiple adjoining under Grammar 1 can be derived with MC-TAG with flexible composition. The two sequences requiring ternary composition under Grammar 1 can be derived when multiple adjoining is permitted.

Figure 6 shows which sequences require which TAG extensions given Grammar 2. The same sequences are derivable with LTAG and MC-TAG. However, allowing flexible composition now allows additional sequences to be derived. Because recasting ternary branching structure as binary branching increases the nodes available to adjoin into, adjoining components into the same node is no longer needed in some cases. The three sequences that required multiple adjoining in Figure 3 now only require flexible composition. Similarly, the two sequences that required same-set multiple adjoining under Grammar 1 can now be derived with the Schabes and Shieber (1994) style multiple adjoining.

## 6 Clitic Climbing and MC-TAG

In Romance languages, pronominal clitics can optionally appear post-verbally, as in (4), or higher in the clause, preceding the tensed verb, as in (5).

- (4)  $V_0 \quad V_1 \quad NP_1 \quad V_2 NP_2$   
 Quiere permitir-**te** ver-**lo**  
 wants to.permit-you to.see-it  
 ‘S/he wants to permit you to see it.’

- (5)  $NP_1 \quad NP_2 \quad V_0 \quad V_1 \quad V_2$   
**Te lo** quiere permitir ver

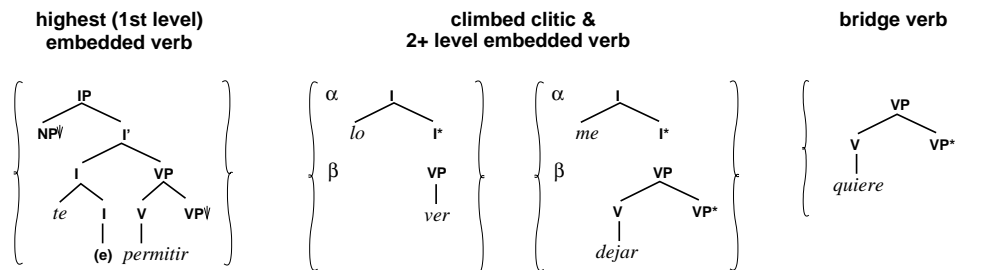


Figure 7: Grammar fragment for clitic climbing patterns. The highest embedded verb anchors a singleton set in which the clitic is climbed. Deeper embedded verbs and their climbed clitics are modeled with an MC-set. Bridge verbs are modeled with an auxiliary tree

As with scrambling, we approach (4) and (5) as different word orders,  $V_0V_1NP_1V_2NP_2$  and  $NP_1NP_2V_0V_1V_2$ , that correspond to the same linguistic dependencies, (a) that between a verb and its clitic argument and (b) that between a verb and its VP argument. Given the grammar fragment in Figure 7, one can see how MC-TAG (without flexible composition or multiple-adjoining) allows the derivation of clitic climbing patterns shown here. Note that the tree for *quiere* in Figure 7 can host additional verbs, allowing clitic climbing across an unbounded number of triggering verbs.

These examples are taken from Bleam (2000), who argues that although sentences involving two climbed clitics and two verbs, such as (6), can be generated with a tree-local MC-TAG, the additional level of embedding in (5), requires the power of set-local MC-TAG.

- (6) **Te lo** permito ver  
 you it I.permit to.see  
 ‘I permit you to see it.’

Interestingly, while (5) and (6) show us that a cluster of two climbed clitics is permissible, our native speaker informants do not accept sentence (7) which involves three levels of embedding and includes a cluster of three climbed clitics, each of which is associated with a different verb. It is not clear whether the absence of clusters of three climbed clitics results from a restriction on clitic climbing per se or whether it is due to other restrictions (e.g. on the clitic cluster template) (Bleam, p.c.) If, however, we assume that this unacceptability is strictly the result of the grammar rather than some other constraints on the output of the grammar, then the need for set-local MC-TAG dissolves.

- (7) \***Mari me te lo** quiere permitir dejar ver.  
 Mari me you it wants to.permit to.let to.see  
 ‘Mari wants you to permit me to see it.’

Further, given the MC-TAG discussed above,  $V_0V_1NP_1V_2NP_2$  and  $NP_1NP_2V_0V_1V_2$  are derivable, but  $NP_1NP_2NP_3V_0V_1V_2V_3$  is not. Above, we noted that assuming a grammar comprised of MC-sets of the type in Figure 7 predicts clitics can climb across an unbounded number of trigger verbs. However, this grammar cannot generate an unbounded number of climbed clitics. The tree for *permitir* does not have enough nodes to host a third clitic-verb MC-set. Thus, the unacceptability of (7) is expected.<sup>8</sup>

## 7 Conclusion

This paper shows that even when we enrich tree-local MC-TAG by allowing flexible composition, not all word order permutations are derivable. Our claim is not that all derivable patterns are equally acceptable, but that we expect un derivable patterns to be clearly unacceptable.

We note two main observations from our study of scrambling. First, even MC-LTAG with flexible composition cannot derive all twenty four permutations of the NPs at three levels of embedding. Specifically, the extensions required to derive more difficult cases involve allowing different degrees of multiple adjoining. The two most difficult cases require a type of composition that is otherwise unmotivated. This is a desirable outcome, as it makes MC-LTAG with flexible composition a candidate for aligning with the linguistic judgments for scrambling. Second, for

<sup>8</sup> Even when MC-TAG is enriched with a flexible composition perspective, Bleam’s (2000) set-local MC-TAG analysis cannot be recast as a tree-local account, leading us to posit that (7) will remain underivable.

MC-LTAG with flexible composition, converting a grammar with non-binary branching elementary trees to a grammar in which binary branching is enforced allows additional scrambling patterns to be derived. Enforcing binary branching requires fewer modifications to MC-LTAG to derive all twenty four permutations. The additional derivations are possible because of the increase in the nodes available nodes to adjoin into. In fact, given enough nodes, the need for multiple-adjoining can be completely eliminated. In our case study, we consider the minimal additional branching required to enforce binary branching. This sets a bound on the additional nodes that can be added. We conjecture that with an additional level of embedding (i.e. 5 NPs), binary branching will no longer provide enough nodes for generating all scrambling patterns using tree-local MC-TAG with flexible composition and multiple adjoining.

Our first observation from our preliminary look at clitic climbing is that the patterns at up to two levels of embedding diverge from the patterns at deeper levels of embedding. Tree-local MC-TAG is sufficient for accounting for the patterns up to two levels of embedding, and also makes at least some correct predictions regarding possible patterns at three levels of embedding. This is similar to the scrambling case in that a tree-local MC-TAG generates all patterns for two levels of embedding, but not for three. This is relevant to a study on recursion being carried out by Joshi (2008, in prep).

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