Realizational Morphology in a Modular Minimalist Grammar

Edward P. Stabler
stabler@ucla.edu

Abstract

A modular minimalist grammar with a realizational morphology is briefly motivated and defined, inspired by recent morphosyntax. A modular grammar identifies and isolates components that are relatively causally independent, making components and their interactions easier to understand, without imprecision or approximation. The modular grammar proposed here assumes a realizational morphology in the sense that the atoms of syntax are not pronounced words, and syntax plays a role in word building. These grammars capture generalizations that previous minimalist grammars, and many other generative grammars, miss. Preliminary support is provided for parsing and learnability results.

In Chomsky and Lasnik (1977) and Lasnik (1981), filters are added to a system of generative rules to block certain generated results. One filter blocks dependent affixes from appearing in structures that do not provide a suitable attachment site:

> . . . *Syntactic Structures* makes the claim that there could be another language just like English but where Affix Hopping is optional. The theory we're looking at now . . . makes the claim that there couldn't be any such language.
>
> Affix Hopping and DO-Support . . . describe but don't capture the . . . generalization: *A stranded affix is no good*. (Lasnik, 2000, p.123)

Various versions of this idea have persisted. Bresnan (2000) says, "To counter the fact that DO is ungrammatical elsewhere, there must be a constraint that penalizes its presence." Grimshaw (1997) and Sag et al. (2020) suggest that we need to account for the fact that DO is "necessary whenever it is possible." Stabler (2001) offers a DO-support transduction on morpheme sequences, to supplement a minimalist grammar (MG) with head movement and affix hopping.

One recent thread through this work is considered here, with particular attention to auxiliary verbs. Kayne (1993) says that while some heads may select their complements, "[t]here is no auxiliary selection rule." Bjorkman (2011) says "BE is not directly selected for, but is instead inserted to support inflectional material that was unable to combine with a main verb." Olivier (2025) argues, "HAVE and BE are allomorphs". And Kalin and Weisser (2025) say, "Combining all the evidence. . . the most adequate model. . . " is one that is non-lexicalist (syntactic word-building), post-syntactic (syntactic atoms have no phonology), and realizational (phonology 'realizes' features but not in lexical increments). Here, a very simple, preliminary kind of grammar with those three properties is defined, plausibly connecting them with parsing and learnability results.[1]

0 Some varieties of grammars

To situate this project, it is useful to briefly review some of the formal grammars that have been used for human languages. A context free grammar uses a finite set of rules like 'S $\rightarrow$ NP VP' to rewrite S and other categories repeatedly until there is a string of words. But context free grammars require large numbers of rules to define human languages even very approximately. For example, extracting a context free grammar from the annotations of the Penn Treebank (Marcus et al., 1994), even when done rather carefully, yields a grammar of well over 10,000 rules, not counting the lexical rules. With that many rules, exhaustive parsing of longer sentences from the *Wall Street Journal* becomes infeasible (Charniak et al., 1998). That set of rules is also a very poor grammar, over- and undergenerating badly. Statistics help these grammars to do better in a probabilistic sense, but they are provably unable to capture some patterns found in human languages: crossing dependencies, reduplication,

[1] For a transparent computer implementation and examples: https://github.com/epstabler/mol25

and non-semilinear patterns.[2]

More expressive grammars grammars have been explored, including tree adjoining grammars (Joshi and Schabes, 1997), (parallel) multiple context free grammars (Seki et al., 1991), combinatory categorial grammars (Steedman and Baldridge, 2011), and minimalist grammars (Stabler, 1997).[3] These can in principle be smaller and less ad hoc than context free grammars, since they can define general patterns found in human languages that context free grammars can only approximate by enumerating instances. But, in practice, these more expressive grammars are still large and complex. Take the minimalist grammars proposed by Stabler and Keenan (2003), for example. Those grammars use 5 rules (three cases of 'merge' and two cases of 'move'). But those grammars do not include head movement or affix hopping. To allow those, Stabler (2001) increases the set of rules to 13, and the rules are rather complex. Stanojević (2019) proposes an alternative, more efficient set of 31 rules. But those grammars still do not include rules for coordination, adjunction, agreement, case marking, DO-support, and other things that have been extensively studied in linguistic theory. Adding those things in a principled way is difficult, because each rule gets so complex, and because the set of rules gets larger.

Linguists have proposed, and this paper confirms: refactoring the problem can help. There are relatively independent regularities in the linear order of constituents, in agreement and case, and in patterns of head displacement. But each rule in generative grammars mentioned above defines all of those at once, the way context free grammars do. Those grammars are all 'monostratal' in the sense that each rule application in those grammars builds all aspects of one part of the linguistic structure. An alternative, modular strategy splits apart relatively independent aspects of language structure and defines each aspect separately. Then each piece of structure must satisfy a number of constraints, rather than being defined all at once by a single, complex rule.

Linguists have been exploring grammars one aspect at a time since the beginning. This kind of modularity was the hallmark of Chomsky (1981) and related work. The more recent minimalist tradition, Chomsky (1995) and following work has aimed to unify and consolidate some aspects of language previously regarded as distinct, and has separated others as 'post-syntactic'. But those post-syntactic components still cover significant aspects of language that remain of interest. So the minimalist perspective on language remains modular.

The minimalist grammars of Stabler and Keenan (2003) and related work are not modular. They fall squarely in the monostratal tradition mentioned earlier. Each rule application builds all aspects of a piece of structure. That facilitates relating the grammars to theories of parsing and learning, but it also makes wide coverage grammars complex.

Here, a modular grammar is proposed that generates structures very similar to the early monostratal minimalist grammars, but where the properties of different aspects of each piece of structure are separately defined. A trivially defined infinite set of binary trees is filtered in a sequence of steps, based on relatively distinct aspects of structure, and then transformed by making rather minor adjustments in agreement and morphological features. This architecture captures the monostratally defined minimalist structures and more.

Six modules are proposed. Each one is a bottom-up tree transduction, that is, each builds an output tree as it processes the input bottom-up, from the leaves to the root, node-by-node. The first 2 steps are partial identity transductions, filtering the initial set of trees that can be built from the atoms. The last 4 steps then make minor adjustments for agreement and morphology. The range of the composed grammar is very similar to the range of a rule-based, monostratal minimalist grammar from the 1990's. In fact, as explained below, I conjecture that the definable string languages are exactly those of the earlier minimalist grammars. But the modular grammars proposed here capture new structures and new generalizations. Instead of many rules for head movement, for example, there is one simpler head movement function with greater expressive power. It is simpler because it can be stated separately from everything else.[4]

[2] Shieber (1985); Culy (1985); Michaelis and Kracht (1997); Kobele (2006).

[3] I have left 'constraint based' grammars out of this list, since they rest on rather different formal foundations (Johnson, 1994; Pullum, 2013), but they do have some properties in common with the modular generative grammars that will be the focus here. Our modularization is distinctively Chomskian, and can be formalized either generatively in terms of tree transducers or in terms of constraints (Graf, 2013).

[4] Hornstein (2024, pp.7-8) proposes "All grammatical relations are merge-mediated" as the "Fundamental Principle of Grammar" (FPG). That FPG sounds like the approach formulated here, since after our merge function (mrg) builds/accepts the initial trees, the following modules either filter or make

1 A modular grammar

The grammars defined here will each be compositions of 6 functions:

$$g = vi \circ lin \circ hm \circ agr \circ sel \circ mrg,$$

where ∘ is standard function composition (often pronounced 'after') and where: mrg builds/accepts binary trees over a set of syntactic atoms; sel maps those trees to themselves if selection features match appropriately; agr matches and instantiates agreement features; hm applies head movement to adjust morphological contents at the leaves (with no change in hierarchical structure); lin maps each tree to its pronounced linear order (with no change in hierarchical structure); and vi, vocabulary insertion, replaces morphological indices with phonologically specified morphs (with no change in hierarchical structure). These 6 functions are defined in the following sections. The composed grammar g is a function from (unpronounceable) binary trees to (hierarchically unchanged but reordered, pronounceable) binary trees. Language variation is attributed to (i) the atoms over which mrg operates and (ii) the rules of vi.

2 mrg

Collins (2002), Chomsky (2007, p.8) and others propose an operation merge which forms binary sets over a lexicon. Here, for the definition of composed grammars, it is convenient to let mrg be the tree transducer which accepts (all and only) ordered binary trees with atoms at the leaves, mapping each such tree to itself. The linear ordering of the tree is inessential, but computationally useful, so we let the range of mrg be the ordered binary trees with lexical items at the leaves and no labels on internal nodes.[5] Lexical items are included as trees with just one node.

We assume that the lexicon is a set of triples, (root, sel-fs, agr-fs), where each root can be thought of as a morphological index that could underlie multiple pronunciations, sel-fs specifies selection features, and agr-fs specifies agreement features. The feature complexes are defined below.

3 sel

As noted by Collins (2002) and others, lexically specified selection requirements seem unavoidable.[6] The function sel accepts only those elements of the range of mrg that satisfy selection requirements, mapping those trees to themselves. Here, we use a notational variant of the selection checking from Kobele (2021), not too different from Stabler (1997). Selection requirements sel-fs are given by a formula fs⊸fs' where fs and fs' are (possibly empty) feature sequences (non-commutative conjunctions), where the features in the antecedent fs are *negative* and those in the consequent fs' are *positive*.[7] If fs is empty, the antecedent is omitted and fs' is simply written as a dot-separated sequence.

At each internal node, sel is defined only if a feature is 'checked'. Selection features are checked bottom-up as follows. At each leaf, the features sel-fs are given by the syntactic atom. Then, moving up through the tree, each internal node has the features (some of which may be checked) at the leaf which is at the end of its left branch, its head. At any internal node with left subtree x and right subtree y, if x has a subtree x' whose first unchecked feature is a positive f, then tree x' must be identical to y (disregarding features checked), those features f in x and x' are checked, and features of y are calculated from x'. This is called *internal merge* or *move*. If x has no subtree x' whose first unchecked feature is a positive f, then the first unchecked feature of y must be positive f, and both of those features are checked, written f̸. This is *external merge*.[8] Feature checking is computed and passed upward in the 'state' of the transduction, without modifying the tree and its features in any way. Schematically:

non-syntactic modifications in them. But Hornstein intends something stricter, suggesting that, in his sense, there can be no modularity in the 'faculty of language', though there may of course be 'interface' operations.

[5] This function is definable by a bottom-up tree transducer (Baker, 1979). A head-first order is enforced in §3 and used at a number of points, but is just a convenience. §3 shows it could be replaced in a set-based computation, identifying the head as the unique child with unchecked 'negative' features. To keep all derivable syntactic objects in the domain of mrg, we allow, at the leaves, any of finitely many sequences of roots built by head movement, and any of finitely many vocabulary items that can replace the roots, as explained below.

[6] But is selection a single, uniform process? And what is selected, exactly? Many issues remain (Kalin and Rolle, 2024; Wurmbrand, 2014; Hirose, 2011; Pollock, 1989).

[7] The ⊸ is from linear logic (Girard, 1995, p.15).

[8] Some linguists have instead assumed a merge-over-move preference (Epstein et al., 2012; Chomsky, 2000, p.106), but there are empirical problems with those proposals (Shima, 2000; Castillo et al., 2009; Abels, 2012, §4.3.1). And it is sometimes proposed that the choice of merge and move is determined by a context-relative optimization (Heck and Müller, 2016). Any of these proposals could be deployed here.

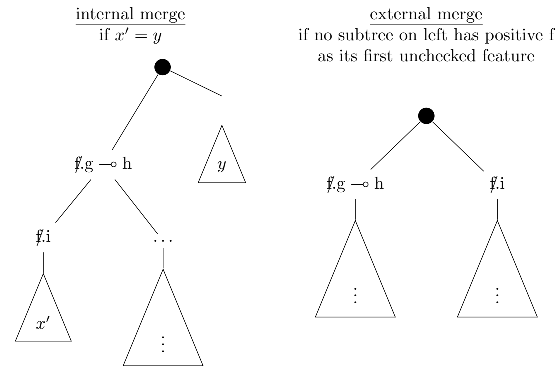


Figure 1 shows an example.

Stabler (1997, 2001) restricts feature checking with a *shortest move constraint*:

(smc) Neither internal nor external merge is possible if it creates a tree in which the first unchecked features of two distinct subtrees are positive and identical (where subtrees related by internal merge are not counted as relevantly distinct).

This blocks analyses in which a single clause has multiple wh phrases extracted by internal merge from a single clause, as in

(1) *What does who say [(who) read (what)]?

(2) *Who says what [(who) read (what)]?

The smc is simple and well-studied.[9] But evidence supports more complex locality conditions, conditions that are still poorly understood.[10]

4 agr

The function agr accepts only those elements of the range of sel that satisfy agreement requirements, mapping those trees to themselves. Following Béjar and Rezac (2009) and others, we assume this check on agreement is 'cyclic' in the sense that it is calculated bottom-up, at each node on paths from leaves to the root.

Adapting Hanson (2025), search is restricted to the first 'd-commanded' element on a specified tier, where a head *d-commands* the heads of its externally merged specifiers from highest to lowest, then the head of its complement, and then whatever the complement head d-commands – in that order.[11] A *tier* $t = \{s_1, \ldots, s_n\}$ is a set of sets of features. A d-commanded *head* h *is on tier t* if and only if some s_i is a subset of the features of h, where those include not only its agr features but also its positive selection features. Recall that atoms are triples (root,sel-fs,agr-fs). Each agr-fs is a set of (tier,feature) probes and feature goals. Probe f looks for a goal in the first d-commanded element on the specified tier, where f is feature with a type separated by :. An unspecified 'probe' ϕ:_ is instantiated by a 'goal' of the same type, a feature like ϕ:3s, in the tier-adjacent d-commanded element.[12]

Developing a suggestion from Chomsky (2000, 2001), Deal (2025b) also argues that agreement affects not only the probe by instantiating, 'valuing' it, but also the goal, 'flagging' it. We adopt that idea here, letting probe ϕ:_ valued by goal ϕ:3s result in ϕ:3s on the probe and ϕ:$\underline{3s}$ on the goal. With this mechanism, we can handle what looked like exceptions to a uniformly downward-looking mechanism.[13] Those exceptions become expected – as occasional morphological realizations of goal-flagging in vocabulary insertion. See Figure 3.[14]

[9]The smc allows feature checking to be computed by a finite state multi bottom up tree transduction. See Kobele et al. (2007); Graf (2023a); Hunter and Frank (2021); Kanazawa (2016, Ex. 5.8); Salvati (2011); Kobele et al. (2007); Michaelis (1998); Stabler (1997, 2011).

[10]Rizzi (2013, 2017); Hein (2024); Major and Torrence (2024); Schurr et al. (2024); Fernández-Serrano (2025); Branan and Erlewine (2025). Note that agr, defined in §4, has a locality condition built in, a kind of relativized minimality. Deal (2025a), a.o. argues that agr locality, when properly formulated, also controls internal merge. There are also arguments that internal merge can target heads rather than just their maximal projections. See Harizanov (2019) and references cited there. These matters are left for future work.

[11]The hypothesis that locality in agreement and selection derives from search has a long history (Chomsky, 2005; Epstein et al., 2020; Chow, 2022; Ke, 2024; Branan and Erlewine, 2025). Syntactic search on tiers is more recent (Graf, 2022, 2023b). In this first sketch of a modular MG, we leave a more careful consideration of search options to future work.

[12]When the lexicon is seen as associating words with structures, it may seem obvious that disjunctive and dependent types are needed, adding significantly to agreement complexity (Shieber, 1986; Johnson, 1988; Eisele and Dörre, 1988; Maxwell and Kaplan, 1989; Dörre and Eisele, 1990; Carpenter, 1992; Francez and Wintner, 2012). But that ambiguity is morphophonological, indicating syntactic composition only indirectly. In this syntax, record types suffice.

[13]These assumptions also make agr and sel feature checking strikingly similar, inviting a unification.

[14]Plausibly, Ermolaeva and Kobele's (2022) argument for the MG-definability of instantiated structures can be adapted to modular grammars with our agr, but further exploration of agr is beyond the scope of this paper. Deal (2025b, Appendix) provides a more elaborate agreement algorithm that allows properties of a probe to change in the course of a derivation (Deal, 2024; Keine, 2019, 2020). Sometimes case is also treated as agreement, but this is controversial. Deal (2025a) and Kidwai (2023) argue, for example, that case should be a head rather than a feature.

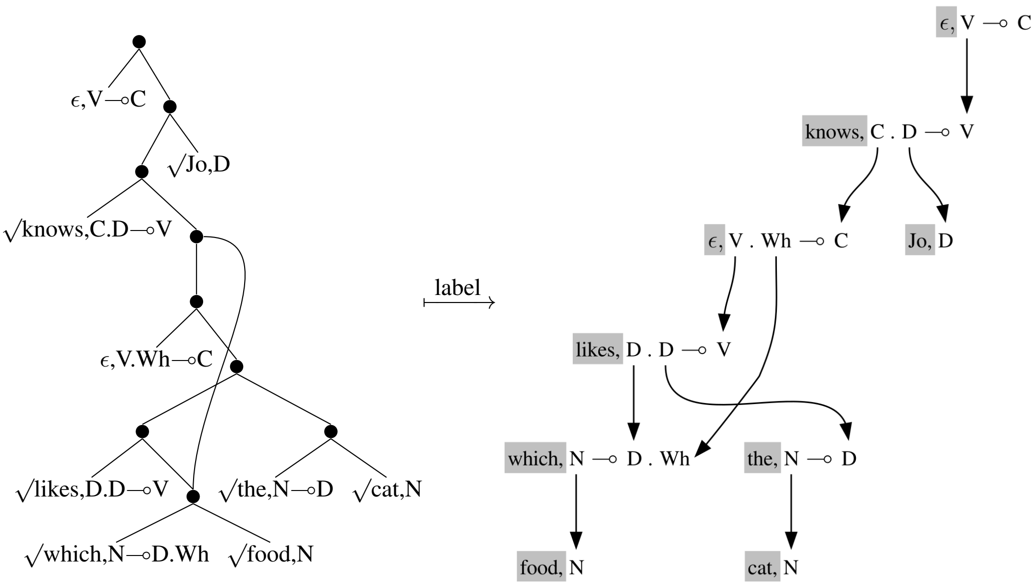


Figure 1: On the left, a tree for *Jo knows which food the cat likes* (showing roots and sel-fs). The function sel checks that a pair of features is checked at each internal node, as described in §3. To show where internal merge (movement) has applied in these graphs, the two identical subtrees for *which food* are shown as one node, but sel applies to the binary tree. At each internal node •, sel requires that the left child is the head, the node with unchecked negative features. The checking relations are made explicit in the corresponding checking graph on the right. Each checking arrow goes from a negative occurrence of a feature to a positive occurrence of that same feature, and each feature is involved in at most one such pairing. In this structure, one feature in the tree remains unchecked: an unchecked, positive C labels the root. Since one pair of features is checked at each node (and smc is respected), as required, sel maps the tree on the left to itself.

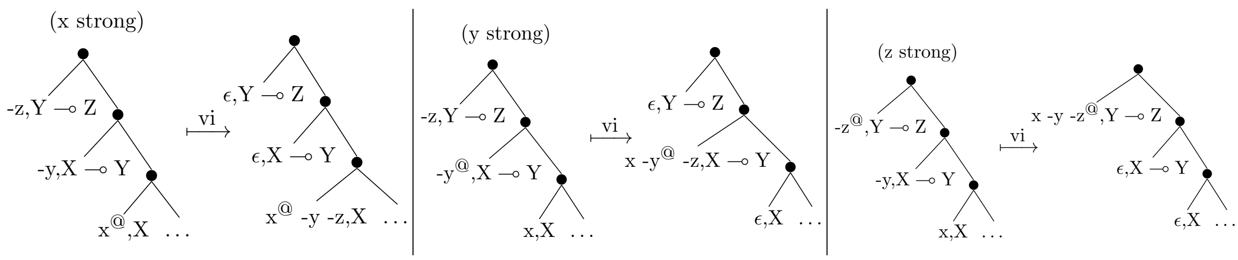


Figure 2: As described in §5, hm acts on three cases with span -z, -y, x. First, the morphs x and -y raise to left-concatenate to -z, in mirror order. Then the complex is placed in the highest strong @ position, leaving the other morph positions empty.

5 hm

Considering the contrast,

(3) Which cat (which cat) chase -s the rat

(4) Which rat (*do) -s the cat chase (which rat)

some have argued that DO is required in (4) because tense is blocked from uniting with the verb by the overt subject *the cat* between the heads T and C in the linearized tree..[15] But this is at best a weak argument for the relevance of linear adjacency in head movement. Since moved elements are featurally distinct, the position of the subject is featurally determined. So while we will agree with the proposal of Chomsky et al. (2023, p.66) and many others that head movement is post-syntactic, distinct from phrase construction, we reject the idea that this operation must apply after linearization, after lin.[16]

Adopting this hypothesis, we formulate a version of head movement inspired by Arregi and Pietraszko (2021). Let a *span* be a sequence of $h_1, \ldots, h_n$ $(n \geq 2)$ where (i) for $i < n$, h_i selects the projection of h_{i+1}, (ii) for $i < n$, h_i has a root marked as morphologically *dependent* with a dash, -√root, (iii) h_n is not marked dependent, and (iv) the sequence is maximal in the sense that h_1 is not the first merge of a higher dependent-marked head. We also require that there is no recursion in spans: no two heads in a span have the same first positive selection feature.

Any head in a span may also be marked *strong*, indicated here by following the root with @.[17] If no head in the span is marked strong, then h_1 is the strongest. Otherwise, the strongest head is the first in the span that is marked @. Bottom-up, the morph of each dependent head raises and left-adjoins a selected independent head (or head complex), and the complex is pronounced at the strongest position. Representing the left-adjunction of morphs by left-concatenation (of roots with their features), this defines the patterns of Figure 2, where the derived order x, y, z of morphs mirrors the syntactic projections Z, Y, X. In the figure, note that in the (x strong) case, both y and x are lowered. In (y strong), x is lowered and z is raised.[18]

Previous minimalist grammars (Stabler, 2001) formalize English subject-auxiliary inversion with a pattern like the (z strong) case of Figure 2, with the complex (verb$^@$ -tense -C$^@$) pronounced in strong question-forming -C$^@$. And English affix-hopping is similar to lowering -tense onto a verb$^@$ with a weak C, like the (x strong) case. See Figure 3.

6 lin

Adapting an idea from Kayne (1994, 2020), Chomsky (1995), Cinque (2023), linear order is adjusted:

(ord) at any node with daughters x, y where head x itself has daughters, reorder to y, x.

And setting the stage for vi, we strip features that are redundant at the interface:[19]

(del) Delete non-final moving elements.

This deletion replaces non-final moving elements, i.e. elements that arguments to an internal merge step, by an empty structure. Then we define: lin = ord ∘ del. See Figure 4.

With del, it is important to remember why internal merge produces structures with identical subconstituents in the first place. Why have those elements in the structure if they are not going to be pronounced? In the current formulation, that question stands out because sel uses an explicit check on whether two subconstituents of unbounded size are identical. And similarly, in tree transducer implementations, transducers with unbounded copying are required (Kobele et al., 2007). With del, why formulate internal merge that way?

Support for internal merge with copying comes from apparent evidence that copies are really there. There is a large literature, but one kind of supporting argument comes from evidence that, in some constructions, non-final copies are sometimes not completely deleted. Yuan (2025) notes, for example, that a number of analyses in the literature claim that deletion of nonfinal occurrences of a fronted

[15] Compare Pollock (1989, §5.5.4), Chomsky (1991, §2.3.1), Bobaljik (1995, §2.1), Sportiche (1998, §5.2.3.1), Embick and Noyer (2001), Bjorkman (2011), Arregi and Pietraszko (2021).

[16] In agreement with, e.g. Branigan (2023, §2.1).

[17] Brody (1997), Svenonius (2016), a.o. also use @. Arregi and Pietraszko (2021) use *.

[18] Cf. Brody (1997, 2000); Adger et al. (2009); Svenonius (2016); Harizanov and Gribanova (2019); Branigan (2023); Giannoula (2025). Kobele (2002) shows how the mirror theory grammars proposed by Brody (1997) are weakly equivalent to MGs. I conjecture that Kobele's result extends to our our similar composed grammars with hm.

[19] Cf. Chomsky et al. (2023, p.26): "An efficiency consideration at [the sensorimotor interface SM] is to pronounce just one (the highest) of a set of copies." But see the discussion of Yuan (2025) a.o. below.

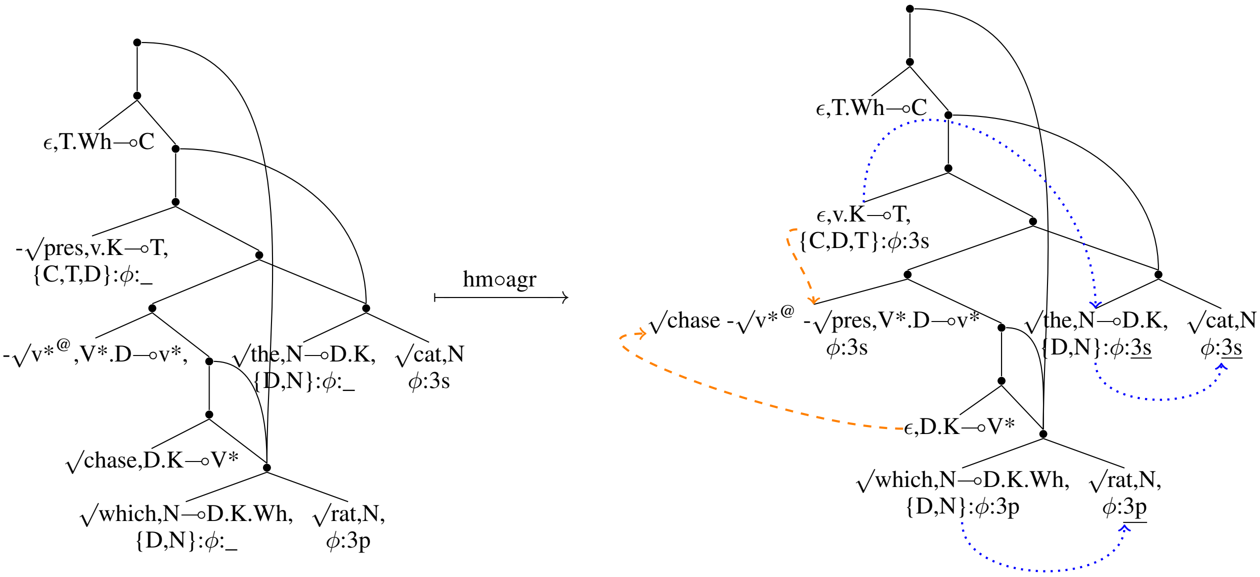


Figure 3: A structure for the embedded clause of *I know [which rat-s the cat chase-s]*. Note that clause structure is elaborated slightly beyond what Figure 1 depicts and atoms are shown with roots, sel-fs and agr-fs. As described in §4, agreement instantiates probe features bottom-up with adjacent elements in spinal d-command sequences on the indicated tier. The dotted arrows show how ϕ:_ probes from D to be valued by its d-commanded N; T probes to find its ϕ value in the d-commanded specifier D. Then, as described in §5, hm creates the head complex V^{*} -$\sqrt{v}^{*@}$ -T as shown by the dashed arrows, putting that complex into the strong v* position. Trees like this that show phrasal and head movements with sel and agr features are complex, but each module is relatively simple.

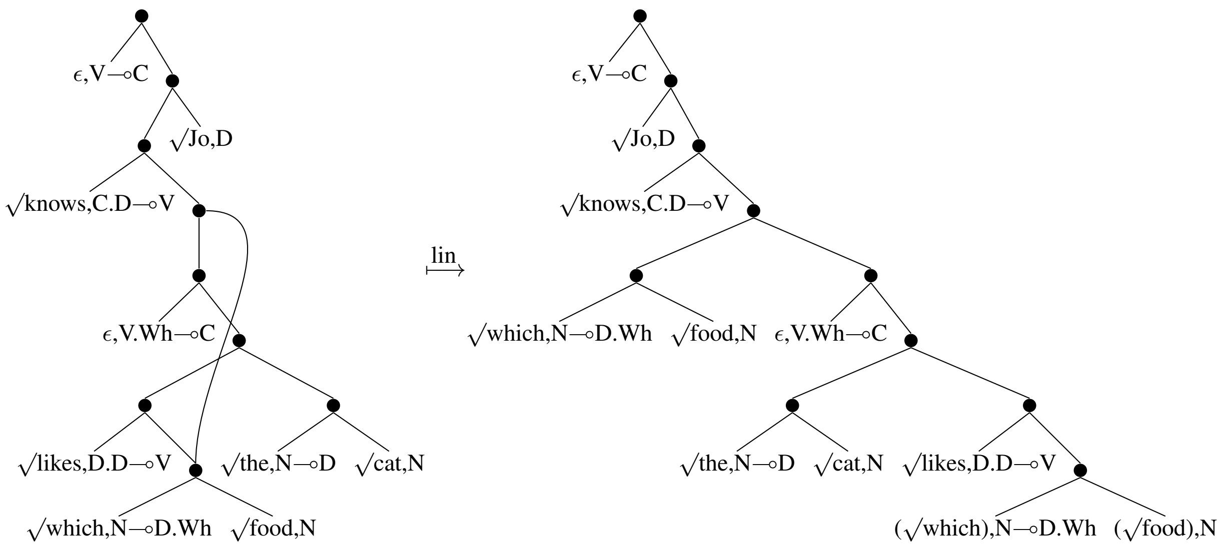


Figure 4: Left, repeated from Figure 1. Right, as described in §6, the result of applying lin. As is often done, instead of emptying non-final copies, those copies are shown with their morphs in parentheses.

verb is blocked when that would leave a tense affix without a host. She then observes a similar pattern in Inuktitut, where deletion of non-final occurrences is blocked when it would strand affixal verbs requiring a DP host. These patterns are inconsistent with the simple deletion process of del.[20] Allowing del to completely remove copies before pronunciation serves as a placeholder for future work.

7 vi

Function vi replaces roots with phonologically instantiated forms, based on syntactic context. For example, the rules

$$\begin{array}{rcl} \sqrt{\text{cat}} & \rightarrow & \text{cat} \\ \phi\text{:3s} & \rightarrow & \text{-s} \end{array}$$

add phonological content to roots in the leaves of the syntactic tree. Representing the phonologically instantiated roots are indicated with standard orthography, the root $\sqrt{\text{cat}}$ in a leaf with ϕ:3s is replaced by phonologically instantiated forms:

$$(\sqrt{\text{cat}},\text{D},\phi\text{:3s}) \quad \Rightarrow \quad (\text{cat -s},\text{D},\phi\text{:3s}).$$

Irregular plurals are handled with special rules:

$$\sqrt{\text{mouse}}\ \phi\text{:3p} \rightarrow \text{mice.}$$

Special rules like this take precedence over the defaults, 'blocking' them, because they are 'more specific' in the sense that they specify more features (Halle and Marantz, 1993; Embick and Marantz, 2008). With this specificity order defined on our finite set of vi rules, we use the first applicable rule.

The domain of this kind of competition among vi rules was widely held to be a single atom, when atoms were morphemes. But as syntactic principles have entered into word building, features that used to be included among those associated with morphemes are now often split away, treated as syntactic heads. When heads are combined by head movement, these features may be reunited. For example, with the rules

$$\begin{array}{rcl} \sqrt{\text{chase}} & \rightarrow & \text{chase} \\ \sqrt{\text{past}} & \rightarrow & \text{-ed,} \end{array}$$

we derive a pronounced form for this complex head from Figure 3, mapping each element pointwise, but preferring rules with the largest numbers of features:

$$(\sqrt{\text{chase}}\ \sqrt{\text{past}}\ \epsilon) \Rightarrow \text{chase -ed.}$$

Adapting ideas from Svenonius (2016) and Haugen and Siddiqi (2016), vi rules can also target spans, where a span is a sequence of heads, each selecting the next, as in hm, but the heads need not be morphologically dependent (marked by -). We replace conditions (ii) and (iii) in the previous definition of *span* in §5 with: (ii') $h_1, \ldots, h_n$ are in the domain of a vi rule. As in hm, we let the highest head be the default strongest. So then, following Haugen and Siddiqi (2016, (7)) we allow this vi rule to derive the Spanish portmanteau *del* from a span that includes a preposition and determiner, indicating the boundaries of syntactic heads with parentheses:

$$(\sqrt{\text{de}})\ (\sqrt{\text{el}}) \quad \rightarrow \quad \text{del.}$$

This rule replaces ($\sqrt{\text{de}}$) with *del* in the preposition, and removes root ($\sqrt{\text{el}}$) from the determiner.

Much is still unsettled in morphology, but this sketch incorporates some of the represented ideas, to be fleshed out in future work. Note that mirror order is not predicted by these vi operations unless operating on a complex formed by hm, and vi also differs from sel in letting rule choice be subject to blocking.

8 Examples

8.1 Nominalization

In standard presentations of logic, each predicate has an arity, but in human languages, a single pronounced form of of a verb like *capture* allows various numbers of arities and can also be a noun with the same arguments, as in *the capture (of markets) (by oligarchs)*. The morph is associated with a kind of event, allowing its various arguments to be expressed or not in various contexts. The verb *destroy* on the other hand has a distinct a nominalized form *destruction*. Rather than treating such coincidences between nominal and verbal forms as accidental, Chomsky (1970) suggests a common underlying form may be mapped to different pronunciations. Here, vi plays that role using the rules,

$$\begin{array}{rcl} (\sqrt{\text{capture}}) & \rightarrow & \text{capture} \\ (\sqrt{\text{destroy}}\ \text{V}) & \rightarrow & \text{destroy} \\ (\sqrt{\text{destroy}}\ \text{N}) & \rightarrow & \text{destruction.} \end{array}$$

If -$\sqrt{}$-tion is a nominalizing head of some kind, then head movement forms a complex to which a very similar vi rule can apply.[21]

[20] Compare also Georgi (2017).

[21] See e.g. Alexiadou and Borer (2020) and references cited there for recent discussion of Chomsky (1970) and recent variants of that kind of proposal.

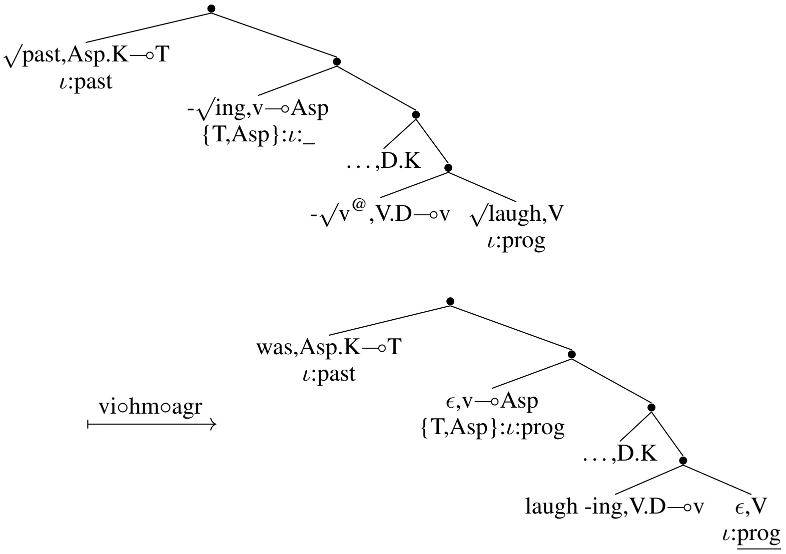


Figure 5: Insertion of English auxiliary BE by vi. An inflectional probe ι:_ on V can be instantiated by ι:past in simple clauses that lack Asp. But here, instantiating bottom-up, ι:prog on Asp values the feature on V, and so valuation by ι:past is not possible. The function vi rescues the structure by inserting $\sqrt{}$BE and mapping $\sqrt{}$BE+$\sqrt{}$past to *was*. The complex placed in the strong v* position by head movement, $\sqrt{}$laugh $\sqrt{}$v* $\sqrt{}$ing, is mapped by vi to *laugh-ing*. Compare e.g. Bjorkman (2011, §2.3.4.1).

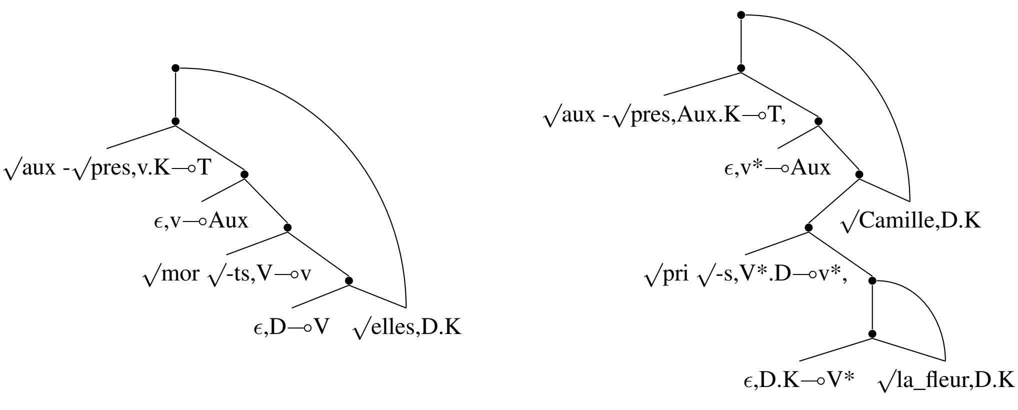


Figure 6: French auxiliary BE and HAVE as allomorphs. In unaccusative on the left, hm raises V $\sqrt{}$mor to v $\sqrt{}$-ts and raises Aux $\sqrt{}$aux to T $\sqrt{}$pres. With the simple vi rules in the text, Aux is realized as BE because it is not adjacent to v* on the {T,v*,v} tier, and so we get *Elles sont mor-ts* ('they died'). On the right, hm raises V $\sqrt{}$pri to v* $\sqrt{}$-s and Aux $\sqrt{}$aux to T $\sqrt{}$pres. Aux with v* adjacent on the tier {T,v*,v} is realized as HAVE, to yield *Camille a pri-s la fleur* ('Camille took the flower'). Compare Olivier (2025, (37),(38)), Bjorkman (2011, §2.4.4.1,(90),(91)).

8.2 English auxiliaries.

While the specification of various pronounced forms of $\sqrt{}$destroy could be entirely a lexical matter, agr, hm and vi get involved in determining how other words are built and pronounced. For example, pronouncing BE requires attention to features:

> Suppose the PF form of a lexical entry is completely unpredictable: the English copula, for example. In this case the lexical coding will provide whatever information the phonological rules need to assign a form to the structure [copula, {F}], where {F} is some set of formal features (tense, person, etc.). (Chomsky, 1995, §4.2.2)

This is exactly our strategy. But unlike Chomsky, we generalize it not just to certain auxiliaries but through the whole vocabulary.

In English, the auxiliary verbs HAVE and BE regularly combine with past and progressive participles, respectively. But in various languages, the appropriate auxiliary for a past participle depends on a number of factors that vary across dialects. Bjorkman (2011) argues that auxiliaries appear not when they are selected but when they are needed to rescue a kind of 'overflow' situation.[22] When a context does not provide a way to express tense on the verb, it can 'spill over' into another form, 'rescuing' the structure. She notes that in Arabic and in the Bantu language Kinande, verbs cannot have both a tense and an aspect marker, so when the main verb has aspect, tense gets expressed on an auxiliary. She argues that English falls into this pattern too, with an analysis that is easily modelled in our grammars, as shown in Figure 5.[23]

8.3 French auxiliaries

In Standard European French passé composé constructions, some verbs require a HAVE auxiliary, while others require BE. One rough approximation is that transitives and unergatives take HAVE, while unaccusatives take BE. Bjorkman (2011) proposes that the presence of an object between a perfective head and the verb blocks agreement between them, yielding HAVE instead BE. Assuming that transitive feature v* is distinct from v, in this simple case, the contrast can be decided by testing whether v* is adjacent on the {T,v*,v} tier:

(Aux) $\rightarrow$ HAVE if v* is {T, v*,v}-adjacent
(Aux) $\rightarrow$ BE

See Figure 6.

Olivier (2025) observes that this simple rule conflicts with the fact that reflexive verbs with direct objects require HAVE. He suggests instead that an Aux head intervenes between T and v_{Prt}, and that Aux is realized as HAVE if person features on T and Aux are not guaranteed to be identical, and otherwise as BE. This gives the basic unaccusative/transitive contrast if Aux always agrees with the internal argument, while T agrees with the closest element on the {C,T,D} tier. But we do not want the realization rules to have to test whether identities are guaranteed. The alternative is to test for the conditions of the guarantee. A fuller integration of Olivier (2025) and similar approaches is left for future work.

9 Conclusions

MG properties adjusted. Previous minimalist grammars have been monostratal, but simplicity and flexibility are enhanced in modular formulation, making understanding and experimentation with alternatives easier. Here, syntactic atoms with unpronounceable roots define the domain of mrg, while agreement, head-movement, linearization, and vocabulary insertion are 'post-syntactic' in the sense of applying after mrg.

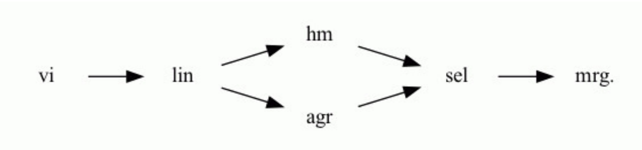
Function vi uses a finite set of (language-specific) rules, applied in an order of decreasing specificity. Defaults get listed as the last case. This kind of competition among alternatives amounts to providing defaults with a kind of negative condition – something that rule-based minimalist grammars do not offer. But since these rules are finite in number and scope, the expressive power of the formalism remains restricted.[24]

We can diagram dependencies among the six modules above with a graph of a sort used in software construction, where each module has those it depends on as its descendants:

[22] There are many rescue analyses for auxiliaries (Embick, 2000; Arregi and Klecha, 2015; Fenger, 2019; Cruschina and Calabrese, 2021). An empirical defense of these is beyond the scope of this paper, where we aim only to explore some computational properties. And see e.g. Pietraszko (2023) for a possible non-realizational account of overflow patterns.

[23] A naive DO-support could be implemented with a vi rule (T $\rightarrow$ DO). But Bjorkman (2011) argues that a broader consideration of *do*-like patterns disconfirms rescue analyses. So we leave this for future work.

[24] It is interesting to compare negation-as-failure and other extensions to Horn clauses in logic programming and type class definitions (Miller, 2022; Bottu et al., 2017). Kanazawa (2007, 2009, 2017) observes that because MCFGs can be elegantly expressed in definite Horn clauses, they are easily parsed in Datalog. Our modular grammars cannot be directly expressed in definite Horn clauses, but as noted just below, we conjecture that these grammars are weakly equivalent to MCFGs.



The function sel relies on the binary structure of mrg. Functions agr and hm rely on the head-complement and internal/external-merge distinctions enforced by sel. The function lin reorders heads and complements, so agr and hm can be slightly simpler if lin applies after them.[25] These consequential generalizations about dependencies among modules – i.e. among aspects of current morphosyntactic theory – are much more explicit in modular grammars than in monostratal theories.

Ongoing research is focused on whether we have properly understood the modules and dependencies. In particular, as research cited above shows, considerable efforts can be regarded as focused on uniting sel and agr in a more general labeling theory, and on uniting hm and vi in a general interface theory.

MG properties preserved: Two conjectures. I conjecture that, if we assume the smc of §3 and the del of §6, the string languages definable by our modular minimalist grammars are definable by rule-based, monostratal minimalist grammars and so, as shown by Michaelis (1998), also by multiple context free grammars (MCFGs). Some support for this conjecture is provided by the discussion and notes above.[26] We know how to parse MCFGs and hence also MGs (Seki et al., 1991; Kallmeyer, 2010; Harkema, 2001), and we have some first, definite ideas about how they can be learned (Clark and Yoshinaka, 2016; Yoshinaka and Clark, 2012).

But is this conjecture with its consequences interesting, when it depends on smc and del, which are clearly not right? I think the conjecture *is* interesting because, plausibly, well-understood computational approaches to MCFGs will extend easily to the better theories that improve on smc and del. This is my second, more speculative conjecture. One bit of evidence for it, relevant to del, comes from the easy extension of MCFGs to 'parallel' MCFGs with unbounded copying, with parsing (Seki et al., 1991) and learning results (Clark and Yoshinaka, 2014). The copying noted by Yuan (2025) and others is very restricted, perhaps shaped in large part by performance factors. Structures like that should not exact the same price in parsing and learning efficiency as parallel MCFGs impose.

Another piece of evidence for the second conjecture, evidence relevant to the smc, comes from the fact that the smc itself is not integrated into the foundations of the grammar. It is a separately stipulated condition. When we find better, empirically well-supported locality conditions, we may be able to impose those in a similar way, without significantly disrupting the basic structure our grammars and the empirical domains they cover. And on the small structures relevant in human language processing, again, less restrictive locality conditions may be compatible with feasible models of human parsing and learning.

New capture of prominent generalizations. With roots in syntactic atoms, we can model something like Chomsky's (1970) nominalization. With vocabulary insertion, we can model something like the Halle and Marantz (1993) competition-based allomorphy. And we can capture something similar to the 'overflow' analyses of auxiliaries proposed by Bjorkman (2011), Olivier (2025) and others. Like earlier DO-support analyses, these involve 'last-resort' rules which are, we conjecture, weakly equivalent to rule-based MGs but more succinct. Rule-based MGs miss those generalizations, but can enumerate the relevant cases.[27]

Acknowledgements

For discussions of earlier versions of this work, thanks to audiences at the Stony Brook University MoL and MG+ meetings, especially Meaghan Fowlie, Thomas Graf, John Hale, and Kristine Yu.

References

Klaus Abels. 2012. *Phases: An Essay on Cyclicity in Syntax*. Linguistische Arbeiten.

David Adger, Daniel Harbour, and Laurel Watkins. 2009. *Mirrors and Microparameters*. Cambridge University Press.

[25] But note that lin ordering arguments are weak, since our Kayne-ian linearization of 2 daughters is only 1 bit of information – so that's 1 bit of information per internal node – and it is efficiently computable.

[26] See fns. 5, 9, 14, 18. A compiler that takes modular grammars (i.e. finite sets of atoms and vi rules) to equivalent MCFGs is also in preparation, adding to the collection of similar compilers for previous mildly context sensitive grammars (Guillaumin, 2004).

[27] Note that we do not really capture the stray affix filter, as formulated by Lasnik in the introduction, but if stray affixes are morphs that cannot occur independently, it is not clear what there is to capture beyond the overflow analyses that rescue certain structures by providing those affixes with hosts.

Artemis Alexiadou and Hagit Borer. 2020. Introduction. In A. Alexiadou and H. Borer, editors, *Nominalization*, pages 1–23. Oxford University Press.

Karlos Arregi and Peter Klecha. 2015. The morphosemantics of english past tense. *Proceedings of North Eastern Linguistic Society*, 45:53–66.

Karlos Arregi and Asia Pietraszko. 2021. The ups and downs of head displacement. *Linguistic Inquiry*, 52:241–289.

Brenda Baker. 1979. Composition of top-down and bottom-up tree transductions. *Information and Control*, 41:186–213.

Susana Béjar and Milan Rezac. 2009. Cyclic agree. *Linguistic Inquiry*, 40:35–73.

Bronwyn Bjorkman. 2011. *BE-ing Default: The Morphosyntax of Auxiliaries*. Ph.D. thesis, MIT.

Jonathan David Bobaljik. 1995. *Morphosyntax: The syntax of verbal inflection*. Ph.D. thesis, MIT.

Gert-Jan Bottu, Georgios Karachalias, Tom Schrijvers, Bruno C. d. S. Oliveira, and Philip Wadler. 2017. Quantified class constraints. *ACM SIGPLAN Notices*, pages 148–161.

Kenyon Branan and Michael Yoshitaka Erlewine. 2025. Locality and (minimal) search. In K.K. Grohmann and E. Leivada, editors, *Cambridge Handbook of the Minimalist Program*. Cambridge University Press.

Phil Branigan. 2023. *The Grammar of Multiple Head Movement*. Oxford University Press.

Joan Bresnan. 2000. Optimal syntax. In J. Dekkers, F. van der Leeuw, and J. van de Weijer, editors, *Optimality Theory: Phonology, Syntax, and Acquisition*, pages 335–385. Oxford University Press.

Michael Brody. 1997. Mirror theory. *UCL Working Papers in Linguistics*, 9.

Michael Brody. 2000. Mirror theory: Syntactic representation in perfect syntax. *Linguistic Inquiry*, 31:29–56.

Bob Carpenter. 1992. *The Logic of Typed Feature Structures*. Cambridge University Press.

Juan Carlos Castillo, John E. Drury, and Kleanthes Grohmann. 2009. Merge over move and the extended projection principle. *Iberia*, 1:53–114.

Eugene Charniak, Sharon Goldwater, and Mark Johnson. 1998. Edge-based best-first chart parsing. *Proceedings of Workshop on Very Large Corpora*, 6:127–133.

Noam Chomsky. 1970. Remarks on nominalization. In N. Chomsky, editor, *Studies on Semantics in Generative Grammar*, pages 1–61. De Gruyter.

Noam Chomsky. 1981. *Lectures on Government and Binding*. Foris, Dordrecht.

Noam Chomsky. 1991. Some notes on economy of derivation and representation. In R. Freidin, editor, *Principles and Parameters in Comparative Grammar*, page 417–454. MIT Press. Reprinted in Chomsky 1995.

Noam Chomsky. 1995. *The Minimalist Program*. MIT Press.

Noam Chomsky. 2000. Minimalist inquiries: The framework. In R. Martin, D. Michaels, and J. Uriagereka, editors, *Step by Step*, pages 89–155. MIT Press. https://isbnsearch.org/isbn/9780262133616.

Noam Chomsky. 2001. Derivation by phase. In M. Kenstowicz, editor, *Ken Hale: A Life in Language*, pages 1–52. MIT Press.

Noam Chomsky. 2005. Three factors in language design. *Linguistic Inquiry*, 36:1–22.

Noam Chomsky. 2007. Approaching UG from below. In U. Sauerland and H.-M. Gärtner, editors, *Interfaces + Recursion = Language?*, pages 1–30. de Gruyter.

Noam Chomsky and Howard Lasnik. 1977. Filters and control. *Linguistic Inquiry*, 8:425–504.

Noam Chomsky, T. Daniel Seely, Robert C. Berwick, Sandiway Fong, M.A.C. Huybregts, Hisatsugu Kitahara, Andrew McInnerney, and Yushi Sugimoto. 2023. *Merge and the Strong Minimalist Thesis*. Cambridge University Press.

Keng Ji Chow. 2022. A novel algorithm for minimal search. *Snippets*, 42:3–5.

Guglielmo Cinque. 2023. *On Linearization: Toward a Restrictive Theory*. MIT Press.

Alexander Clark and Ryo Yoshinaka. 2014. Distributional learning of parallel multiple context-free grammars. *Machine Learning*, 96:5–31.

Alexander Clark and Ryo Yoshinaka. 2016. Distributional learning of context-free and multiple context-free grammars. In J. Heinz and J.M. Sempere, editors, *Topics in Grammatical Inference*, pages 143–172. Springer.

Chris Collins. 2002. Eliminating labels. In S.D. Epstein and T.D. Seely, editors, *Derivation and Explanation*, pages 42–64. Blackwell.

Silvio Cruschina and Andrea Calabrese. 2021. Fifty shades of morphosyntactic microvariation. In M.-O. Hinzelin and E.-M. Remberger, editors, *Formal Approaches to Romance Morphosyntax*, pages 145–198. de Gruyter.

Christopher Culy. 1985. The complexity of the vocabulary of Bambara. *Linguistics and Philosophy*, 8:345–352.

Amy Rose Deal. 2024. Interaction, satisfaction, and the PCC. *Linguistic Inquiry*, 55:39–94.

Amy Rose Deal. 2025a. Case sensitivity reflects case structure: Agreement, extraction, and clitics. UC Berkeley.

Amy Rose Deal. 2025b. Current models of agree. *Berkeley Papers in Formal Linguistics*, 4. Forthcoming in J. Crippen, R.-M. Déchaine and H. Keupdjio, editors, *Move and Agree: Towards a formal typology*. John Benjamins.

Jochen Dörre and Andreas Eisele. 1990. Feature logic with disjunctive unification. *Proceedings of Computational linguistics*, 13:100–105.

Andreas Eisele and Jochen Dörre. 1988. Unification of disjunctive feature descriptions. *Proceedings of Association for Computational Linguistics*, 26.

David Embick. 2000. Features, syntax, and categories in the Latin perfect. *Linguistic Inquiry*, 31:185–230.

David Embick and Alec Marantz. 2008. Architecture and blocking. *Linguistic Inquiry*, 39:1–53.

David Embick and Rolf Noyer. 2001. Movement operations after syntax. *Linguistic Inquiry*, 32:555–595.

Samuel D. Epstein, Hisatsugu Kitahara, and T. Daniel Seely. 2012. Labeling by minimal search. *Linguistic Inquiry*, 45:463–481.

Samuel D. Epstein, Hisatsugu Kitahara, and T. Daniel Seely. 2020. Unifying labeling under minimal search in single- and multiple-specifier configurations. *Coyote Papers: Working Papers in Linguistics, Linguistic Theory at the University of Arizona*.

Marina Ermolaeva and Gregory M. Kobele. 2022. Agreement as information transmission. *Syntax*, 25:466–507.

Paula Fenger. 2019. Size matters: Auxiliary formation in the morpho-syntax and the morpho-phonology. *Proceedings of North East Linguistic Society*, 49.

Irene Fernández-Serrano. 2025. Phase theory: inception, developments and challenges. In K.K. Grohmann and E. Leivada, editors, *Cambridge Handbook of the Minimalist Program*. Cambridge University Press.

Nissim Francez and Shuly Wintner. 2012. *Unification Grammars*. Cambridge University Press.

Doreen Georgi. 2017. Patterns of movement reflexes as the result of the order of merge and agree. *Linguistic Inquiry*, 48:585–626.

Mina Giannoula. 2025. Deciphering mirror principle violations. *Morphology*, 35:305–338.

Jean-Yves Girard. 1995. Linear logic: Its syntax and semantics. In J.-Y. Girard, Y. Lafont, and L. Regnier, editors, *Advances in Linear Logic*, pages 1–42. Cambridge University Press.

Thomas Graf. 2013. *Local and Transderivational Constraints in Syntax and Semantics*. Ph.D. thesis, UCLA.

Thomas Graf. 2022. Typological implications of tier-based strictly local movement. *Proceedings of Society for Computation in Linguistics*, 5:184–193.

Thomas Graf. 2023a. Minimalism and computational linguistics. *LingBuzz*, 005855.

Thomas Graf. 2023b. Subregular tree transductions, movement, copies, traces, and the ban on improper movement. *Proceedings of Society for Computation in Linguistics*, 6:289–299.

Jane Grimshaw. 1997. Projection, heads, and optimality. *Linguistic Inquiry*, 28:373–422.

Matthieu Guillaumin. 2004. Conversions between mildly sensitive grammars. UCLA and École Normale Supérieure, Paris.

Morris Halle and Alec Marantz. 1993. Distributed morphology and the pieces of inflection. In K. Hale and S.J. Keyser, editors, *The View from Building 20*, pages 111–176. MIT Press.

Kenneth Hanson. 2025. Tier-based strict locality and the typology of agreement. *Journal of Language Modeling*, 13:43–97.

Boris Harizanov. 2019. Head movement to specifier positions. *Glossa*, 4:140.

Boris Harizanov and Vera Gribanova. 2019. Whither head movement? *Natural Language and Linguistic Theory*, 37:461–522.

Henk Harkema. 2001. *Parsing Minimalist Languages*. Ph.D. thesis, University of California.

Jason D. Haugen and Daniel Siddiqi. 2016. Towards a restricted realization theory. In D. Siddiqi and H. Harley, editors, *Morphological Metatheory*. John Benjamins.

Fabian Heck and Gereon Müller. 2016. On accelerating and decelerating movement. In G. Legendre, M. Putnam, H. de Swart, and E. Zaroukian, editors, *Optimality-Theoretic Syntax, Semantics, and Pragmatics*, pages 78–110. Oxford University Press.

Johannes Hein. 2024. Category-sensitive escape from islands in Limbum and Asante Twi. *Languages*, 9:317.

Tomio Hirose. 2011. *Origins of Predicates: Evidence from Plains Cree*. Routledge.

Norbert Hornstein. 2024. *The Merge Hypothesis*. Cambridge University Press.

Tim Hunter and Robert Frank. 2021. Comparing methods of tree-construction across mildly context-sensitive formalisms. *Proceedings of Society for Computation in Linguistics*, 4:355–358.

Mark Johnson. 1988. *Attribute Value Logic and The Theory of Grammar*. CSLI. https://isbnsearch.org/isbn/9780937073360.

Mark Johnson. 1994. Two ways of formalizing grammars. *Linguistics and Philosophy*, 17:221–248.

Aravind K. Joshi and Yves Schabes. 1997. Tree-adjoining grammars. In G. Rozenberg and A. Salomaa, editors, *Handbook of Formal Languages, Volume 3: Beyond Words*, pages 69–124. Springer.

Laura Kalin and Nicholas Rolle. 2024. Deconstructing subcategorization. *Linguistic Inquiry*, 55:197–218.

Laura Kalin and Philipp Weisser. 2025. Minimalism and morphology. In K.K. Grohmann and E. Leivada, editors, *Cambridge Handbook of the Minimalist Program*. Cambridge University Press.

Laura Kallmeyer. 2010. *Parsing Beyond Context-Free Grammars*. Springer.

Makoto Kanazawa. 2007. Parsing and generation as Datalog queries. *Proceedings of Association for Computational Linguistics*, 45:176–183. https://aclanthology.org/P07-1023/.

Makoto Kanazawa. 2009. The pumping lemma for well-nested multiple context-free languages. *Developments in Language Theory*, 13:312–325.

Makoto Kanazawa. 2016. Formal grammar: An introduction. Lecture 5: Mildly context-sensitive languages. Lecture notes, Hosei University.

Makoto Kanazawa. 2017. Parsing and generation as Datalog query evaluation. *Journal of Logics and their Applications*, 4. http://www.collegepublications.co.uk/downloads/ifcolog00013.pdf.

Richard S. Kayne. 1993. Toward a modular thoery of auxiliary selection. *Studia Linguistica*, 47:1–31.

Richard S. Kayne. 1994. *The Antisymmetry of Syntax*. MIT Press.

Richard S. Kayne. 2020. Antisymmetry and externalization. *LingBuzz*, 005554.

Alan Hezao Ke. 2024. Can agree and labeling be reduced to minimal search? *Linguistic Inquiry*, 55:849–870.

Stefan Keine. 2019. Selective opacity. *Linguistic Inquiry*, 50:13–61.

Stefan Keine. 2020. *Probes and their horizons*. MIT Press.

Sana Kidwai. 2023. *Voice, Case and the External Argument: The Perspective from Urdu*. Ph.D. thesis, University of Cambridge.

Gregory M. Kobele. 2002. Formalizing mirror theory. *Grammars*, 5:177–221.

Gregory M. Kobele. 2006. *Generating Copies*. Ph.D. thesis, UCLA.

Gregory M. Kobele. 2021. Minimalist grammars and decomposition. Leipzig University. https://home.uni-leipzig.de/gkobele/files/unpub/ Kobele21MGsAndDecomposition.pdf.

Gregory M. Kobele, Christian Retoré, and Sylvain Salvati. 2007. An automata-theoretic approach to minimalism. In *Model Theoretic Syntax at 10, ESSLLI'07*.

Howard Lasnik. 1981. Restricting the theory of transformations. In N. Hornstein and D. Lightfoot, editors, *Explanation in Linguistics*, pages 125–145. Longman.

Howard Lasnik. 2000. *Syntactic Structures Revisited*. MIT Press.

Travis Major and Harold Torrence. 2024. Escape from noun complement clauses in Avatime. *Languages*, 9:339.

Mitchell Marcus, Grace Kim, Mary Ann Marcinkiewicz, Robert MacIntyre, Ann Bies, Mark Ferguson, Karen Katz, and Britta Schasberger. 1994. The Penn Treebank: annotating predicate argument structure. *Proceedings of Workshop on Human Language Technology*, pages 114–119.

John T. Maxwell and Ronald M. Kaplan. 1989. An overview of disjunctive constraint satisfaction. *Proceedings of International Workshop on Parsing Technologies*, 1:18–27.

Jens Michaelis. 1998. Derivational minimalism is mildly context-sensitive. *Proceedings of Logical Aspects of Computational Linguistics*, 3:179–198.

Jens Michaelis and Marcus Kracht. 1997. Semilinearity as a syntactic invariant. *Proceedings of Logical Aspects of Computational Linguistics*, 1:329–345.

Dale Miller. 2022. A survey of the proof-theoretic foundations of logic programming. *Theory and Practice of Logic Programming*, 22:859–904.

Marc Olivier. 2025. A syntactic account of auxiliary selection in French. *Probus*, 31.

Asia Pietraszko. 2023. Cyclic selection. *Linguistic Inquiry*, 54:350–377.

Jean-Yves Pollock. 1989. Verb movement, universal grammar, and the structure of IP. *Linguistic Inquiry*, 20:365–424.

Geoffrey K. Pullum. 2013. The central question in comparative syntactic metatheory. *Mind and Language*, 28:492–521.

Luigi Rizzi. 2013. Locality. *Lingua*, 130:169–186.

Luigi Rizzi. 2017. Locality and the functional sequence in the left periphery. In E. Aboh, E. Haeberli, G. Puskás, and M. Schönenberger, editors, *Elements of Comparative Syntax*, pages 319–348. De Gruyter.

Ivan A. Sag, Rui P. Chaves, Anne Abeillé, Bruno Estigarribia, Dan Flickinger, Paul Kay, Laura A. Michaelis, Stefan Müller, Geoffrey K. Pullum, Frank Van Eynde, and Thomas Wasow. 2020. Lessons from the English auxiliary system. *Journal of Linguistics*, 56:87–155.

Sylvain Salvati. 2011. Minimalist grammars in the light of logic. In S. Pogodalla, M. Quatrini, and C. Retoré, editors, *Logic and Grammar*, pages 81–117. Springer.

Hagay Schurr, Jason Kandybowicz, Abdoulaye Laziz Nchare, Tysean Bucknor, Xiaomeng Ma, Magdalena Markowska, and Armando Tapia. 2024. Absence of clausal islands in Shupamem. *Languages*, 9:7.

Hiroyuki Seki, Takashi Matsumura, Mamoru Fujii, and Tadao Kasami. 1991. On multiple context-free grammars. *Theoretical Computer Science*, 88:191–229.

Stuart M. Shieber. 1985. Evidence against the context-freeness of natural language. *Linguistics and Philosophy*, 8:333–344.

Stuart M. Shieber. 1986. *An Introduction to Unification-Based Approaches to Grammar*. CSLI.

Esturo Shima. 2000. A preference for move over merge. *Linguistic Inquiry*, 32:375–385.

Dominique Sportiche. 1998. *Partitions and Atoms of Clause Structure*. Routledge.

Edward P. Stabler. 1997. Derivational minimalism. *Proceedings of Logical Aspects of Computational Linguistics*, 1:68–95.

Edward P. Stabler. 2001. Recognizing head movement. *Proceedings of Logical Aspects of Computational Linguistics*, 4:254–260.

Edward P. Stabler. 2011. Computational perspectives on minimalism. In C. Boeckx, editor, *Oxford Handbook of Linguistic Minimalism*, pages 617–641. Oxford University Press.

Edward P. Stabler and Edward L. Keenan. 2003. Structural similarity within and among languages. *Theoretical Computer Science*, 293:345–363.

Miloš Stanojević. 2019. On the computational complexity of head movement and affix hopping. *Proceedings of Formal Grammar*, 24:101–116. Springer LNCS 11668.

Mark Steedman and Jason Baldridge. 2011. Combinatory categorial grammar. In R. Borsley and K. Börjars, editors, *Non-Transformational Syntax*, pages 181–224. Wiley.

Peter Svenonius. 2016. Spans and words. In H. Harley and D. Siddiqi, editors, *Morphological Metatheory*, pages 199–220. John Benjamins, Amsterdam.

Susi Wurmbrand. 2014. The merge condition: A syntactic approach to selection. In P. Kosta, S.L. Franks, T. Radeva-Bork, and L. Schürcks, editors, *Minimalism and Beyond*, pages 130–166. John Benjamins.

Ryo Yoshinaka and Alexander Clark. 2012. Polynomial time learning of some multiple context-free languages with a minimally adequate teacher. In *Formal Grammar 2010, 2011*. Springer.

Michelle Yuan. 2025. Morphological conditions on movement chain resolution. *Natural Language and Linguistic Theory*, 43:509–562.