A Common Derivation for Parsing and Generation with Expectation-Based Minimalist Grammars (e-MGs)

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Abstract

Expectation-based Minimalist Grammars (e-MGs) are simplified versions of the (Conflated) Minimalist Grammars, (C)MGs, formalized by Stabler (Stabler 1997; Stabler 2011; Stabler 2013) and Phase-based Minimalist Grammars, PMGs (Chesi 2007; Chesi 2005; Stabler 2011). The crucial simplification consists of driving structure building only using lexically encoded categorial top-down expectations. The commitment on a top-down procedure (in e-MGs and PMGs, as opposed to (C)MGs, Chomsky, 1995; Stabler, 2011) allows us to define a core derivation that is the same in both parsing and generation (Momma & Phillips 2018).

1 Introduction

Minimalism (Chomsky 1995; Chomsky 2001) is an elegant transformational grammatical framework that defines structural dependencies in phrasal (i.e. hierarchical) terms simply relying on one core structure building operation, Merge, that combines lexical items and the result of other Merge operations. (1).a is the representative result of two ordered Merge operations (i.e. Merge(γ, Merge(α, β)) both taking the items α, β and γ directly from the lexicon, while (1).b relies on the so called Internal Merge (Move): the re-Merge of an item that was already merged in the structure.

(1)	a. $[\gamma\ [\alpha,\ \beta]]$	*Merge* only
	b. $[\beta\ [\gamma\ [\alpha,\ \__{\beta}]]$	*Merge + Move*

As result, Move connects the item at the edge of the structure (β) with a trace ($\__{\beta}$), a phonetically empty copy of the item that in a previous Merge operation combined with a hierarchically lower item (α in (1).b). In both (Conflated) Minimalist and Phase-based Minimalist Grammars ([C]MGs and PMGs respectively) Merge and Move are feature-driven operations, that is, a successful operation must be triggered by the relevant (categorial) features matching, and, once these features are used, they get deleted. Consequently, a feature pair is always responsible for each operation (unless specific features are left unerased after a successful operation, as in raising predicates and successive cyclic movement, Stabler 2011). One crucial difference between PMGs and MGs is that while MGs operate from-bottom-to-top, as indicated in (2), PMGs structure building operations apply top-down as schematized in (3)[1]:

(2) $Merge(\alpha_{=X},\ {}_{X}\beta) = [\alpha\ [\alpha_{\cancel{=X}}\ {}_{\cancel{X}}\beta]]$ *MGs*
$Move({}_{+Y}\alpha,\ [\ldots\ \beta_{-Y}\ \ldots]) =$
$[\alpha\ [\beta_{\cancel{-Y}}\ [{}_{\cancel{+Y}}\alpha\ [\ldots\ \beta_{-Y}\ \ldots]]]]$

(3) $Merge(\alpha_{=X},\ {}_{X}\beta) = [\alpha_{\cancel{=X}}\ [{}_{\cancel{X}}\beta]]$ *PMGs*
$Move([\alpha_{=S\ \cancel{+Y}}[{}_{\cancel{Y}\ Z}\ \beta]]) =$
$[\alpha_{\cancel{=S}\ \cancel{+Y}}[{}_{\cancel{Y}\ Z}\ \beta]\ {}_{S}[\ldots\ ({}_{=Z}\ [{}_{Z}\ \beta])\ \ldots]]$

Another relevant difference between the two approaches is related to the implementation of Move: MGs use the “+/-” feature distinction and the same deletion procedure after matching, while PMGs do not use “-” features and simply assume that both “+” and “=” select categorial features, which are deleted after Merge. In PMGs, “+” features force memory storage and hence the movement (downward) of the licensed item, until the relevant prominent category identifying the moved item (*Z* in (3)) is selected. If no proper selection is found, the sentence is ungrammatical. CMG as well dispenses the grammar with the +/- feature distinction and only relies on select features (=*X*), but it must assume that feature deletion can be procrastinated (again, for instance, in

[1] *α* and *β* are lexical items, =*X* indicates the selection of *X*, where X is a categorial feature. Lexical items are tuples consisting of selections/expectations (=*X*) and categories (X, i.e. selected/expected features); for convenience, select features are expressed by rightward subscripts, and categories as leftward subscripts. Similarly, Move is driven by licensing (-*Y*, leftward subscripts) and licensors (+*Y*, rightward subscripts) features (Stabler 2011).

raising predicates). Despite the fact that, from a generative point of view, all these formalisms are equivalent and they all fall under the so called mildly-context sensitive domain (Stabler 2011), it is worth to appreciate the dynamics of structure building "on-line", namely how the derivation unrolls, word by word. Taking the MGs lexicon (4), the expected constituents in (1) are built adding items to the left-edge of the structure at each Merge/Move application, as described in (5).

(4) $Lex_{MG} = \{[{}_{Y}\alpha_{=X}], [{}_{X\ -Z}\beta], [\gamma_{=Y\ +Z}]\}$

(5) i. $Merge({}_{Y}\alpha_{=X}, {}_{X\ -Z}\beta) = [{}_{Y}\alpha\ [\alpha_{\cancel{=X}}\ {}_{\cancel{X}\ -Z}\beta]]$

ii. $Merge(\gamma_{=Y\ +Z}, [{}_{Y}\alpha\ [\alpha\ {}_{-Z}\beta]]) =$

$[\gamma_{\cancel{=Y}\ +Z}\ [{}_{\cancel{Y}}\alpha\ [\alpha\ \ {}_{-Z}\beta]]]$

iii. $Move\ ([\gamma_{+Z}\ [\alpha\ [\alpha\ {}_{-Z}\beta]]]) =$

$[[{}_{\cancel{-Z}}\beta]\ \gamma_{\cancel{+Z}}\ [\gamma\ [\alpha\ [\alpha\ {}_{\_\beta}]]]$

An equivalent structure is obtained in PMGs[2] as shown in (7). Notice a minimal difference in the lexicon (6): the absence of the "-" features.

(6) $Lex_{PMG} = \{\ [{}_{Y}\alpha_{=X}], [{}_{Z\ X}\ \beta], [\gamma_{+Z\ =Y}]\ \}$

(7) i. $Merge({}_{Z\ X}\beta, \gamma_{+Z\ =Y}) = [[{}_{\cancel{Z}\ X}\beta]\ \gamma_{\cancel{+Z}\ =Y}]$

${}_{X}\beta \longrightarrow M$

ii. $Merge([[\beta]\ \gamma\ {}_{=Y}], {}_{Y}\alpha\ {}_{=X}) =$

$[[\beta]\ \gamma\ [_{(\gamma)}\ {}_{\cancel{=Y}}\ [{}_{\cancel{Y}}\alpha\ {}_{=X}]]$ $\qquad M = \{{}_{X}\beta\}$

iii. $Move([[\beta]\ \gamma\ [_{(\gamma)}\ [\alpha\ {}_{=X}]], {}_{X}\beta) =$

$[[\beta]\ \gamma\ [_{(\gamma)}\ [\alpha_{\cancel{=X}}\ [_{(\alpha)}\ {}_{\cancel{X}\_\beta}]]]]$ $\qquad {}_{X}\beta \longleftarrow M$

The result of the two derivations is (strongly) equivalent in hierarchical (and dependency) terms. The simplicity, in pre-theoretical terms, of the two descriptions is comparable: while PMGs must postulate the *M* storage to implement Move (as result of the missing selection of a categorial feature), MGs must postulate independent workspace to build nontrivial left-branching structures, for instance before merging a multi-word subject like "the boy" with its predicate (e.g., "runs"). Furthermore, both formalisms must restrict the behavior either of the *M* buffer operativity or the accessibility to the *-f* features to limits the Move operation (e.g., island constraints, Huang, 1982).

1.1 Top-Down is Better

There are at least three reasons to commit ourselves to the top-down orientation instead of remaining agnostic or relying on the mainstream Minimalist brick-over-brick (from-bottom-to-top) approach (Chesi 2007): First, the order in which the structure is built is grossly transparent with respect to the order in which the words are processed in real-life tasks, both in generation and in parsing in PMGs, but not in MGs.

Second, in PMGs, the simple processing order of multiple expectations is sufficient to distinguish between sequential (the last expectation of a given lexical item) and nested expectations (any other expectation): The first qualifies as the transparent branch of the tree (i.e. it is able to license pending items from the superordinate selecting item), while constituents licensed by nested expectations qualify as configurational islands (Bianchi & Chesi 2006; Chesi 2015). Moreover, successive cyclic movement is easily described in PMGs without relying on feature checking at any step or non-deterministic assumptions on features deletion (Chesi 2015) contrary to (C)MGs.

A third logical reason to prefer the top-down orientation over the bottom-up alternative is related to the unicity of the root node in tree graphs. As anticipated, the creation of complex (binary) branching structures poses a puzzle for (C)MGs: Independent workspaces must be postulated, namely [the boy] and [sings …] phrases must be created before one can merge with the other:

(8) $[_{VP}$ **$[_{DP}$** the boy**]** **$[_{V}$** sings $[_{DP}$ a song]**]**]

This is the case of "complex" subject or adjunct (i.e., non-projecting constituents which are simply composed by more than one lexical item) that must be the result of (at least) one independent Merge operation, before this can merge with the relevant predicate (e.g. $[_{V}$ sings …][3] in (8)). Processing these constituents represents a major difference between (bottom-up) MGs and (top-down) PMGs derivations. While MGs must decide where to start from (and both solutions are possible and forcefully logically independent from parsing or generation, which undeniably proceed "left-right"), PMGs take advantage of the "single root condition" (Partee, Meulen & Wall 1993: 439) and avoid this problem:

(9) In every well-formed constituent structure tree, there is exactly one node that dominates every node.

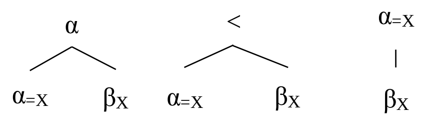
As indicated in (3), the binary operation Merge simply produces a hierarchical dependency in which the dominating (asymmetrically C-

[2] Move is implemented using a Last-In-First-Out addressable memory buffer M, where the item (*β*) with unselected categorie(s) (*X*) is stored ("${}_{X}\beta \rightarrow M$") and retrieved ("${}_{X}\beta \leftarrow M$") when selected (i.e. "*=X*").

[3] Considering the inflection "-s" as part of the lexical element or by (head) moving the root "sing-" to T is uninfluential here. This sort of head movement is implemented lexically in e-MGs (e.g. $[_{T\ (=V\ V)}$ eats …].

commanding, in the sense of Kayne 1994) item is above the dominated (C-commanded) one. This is compatible with Stabler notation (10).a-b and plainly solves the ambiguity of the nature of the “label” of the constituent (Rizzi 2016). In this sense, PMGs (and the e-MGs discussed later) can adopt directly a more concise description, that is (10).c, more transparent with respect to the (Universal) Dependency approach (Nivre et al. 2017): Elements are “dependent” when they Merge.

(10) a. MGs b. (C)MGs c. (P/e-)MGs



The higher node (possibly the root) is always the selecting item (a *probe*, in minimalist terms), and it is the first item to be processed. This does not necessarily imply that this item is linearized before the selected category (the *goal*, in minimalist terms): if the selecting node has multiple selection needs, it must remain to the right-edge of the structure to license, locally, the other(s) selection expectation(s). E.g., if $[\alpha_{=X\ =Y}]$, $[_{X}\beta]$ and $[_{Y}\gamma]$, then:

(11) $[\alpha_{\cancel{=X}\ =Y}\ [_{\cancel{X}}\beta]\ [(\alpha_{\cancel{=Y}})\ [_{\cancel{Y}}\gamma]]]$

In this case, <α, β, γ> would be the default linearization, but it is easy to derive <β, α, γ> instead, assuming a simple parameterization on spell-out in case of multiple select features.

Here, I will argue that we can push further this intuition and only rely on (categorial) expectations, encoded in the lexical items, to guide the derivation. This leads to the so-called expectation-based Minimalist Grammars (e-MGs).

In the following sections, I will sketch a simple formalization for e-MGs (§2), and the core derivation algorithm (§3) that would be used both in Generation and Parsing tasks (§3.2).

2 The Grammar

As (C/P)MGs, e-MGs include a specification of a lexicon (*Lex*) and a set of functions (*F*), the structure building operations. The lexicon, in turn, is a finite set composed by words each consisting of phonetic/orthographic information (*Phon*) and a combination of categorical features (*Cat*), expressing *expect(ations)*, *expected* and *agreement* categories[4]. In the end, an optional set of Parameters (*P*) (see Chesi 2021), inducing minimal modifications to the structure building operations *F* and, possibly, to the *Cat* set, under the fair assumption that *F* and *Cat* are universal. More precisely, any e-MG is a 5-tuple such that:

(12) *G* = (*Phon*, *Cat*, *Lex*, *F*, *P*), where

Phon, a finite set of phonetic/orthographic features (i.e., orthographic forms representing words, e.g., “the”, “smiles”)
Cat, a finite set (morphosyntactic categories, that can be *expect*, *expected* or *agreement* features e.g., “D”, “V”… “gen(der)”, “num(ber)”, “pl(ural)” etc.)
Lex, a set of expressions built from *Phon* and *Cat* (the lexicon)
F, a set of partial functions from tuples of expressions to expressions (the structure building operations)
P, a finite set of minimal transformations of *F* and/or *Cat* (the parameters), producing *F'* and *Cat'*, respectively.

2.1 Lexical Items and Categories

Each lexical item *l* in *Lex*, namely each word, is a 4-tuple defined as follows[5]:

(13) l = (*Ph*, *Exp*(*ect*), *Exp*(*ect*)*ed*, *Agr*(*ee*)),

Phon, from *Phon* in *G* (e.g., “the”)
Exp, a finite list of ordered features from *Cat* in *G* (the category/ies that the item expects will follow, e.g., =*N*)
Exped is a finite list of ordered features from *Cat* in *G* (the category/ies that should be licensed/expected, e.g., *N*)
Agr(ee) is a structured list of features from *Cat* in G (e.g., *gen.fem*, *num.pl*)

All *Exp(ect)*, *Exp(ect)ed* and *Agr(ee)* features are then subsets of *Cat* in G. In *Agr*, for instance, a feminine gender specification (*gen.fem*) expresses a subset relation (i.e., “feminine” ⊆ “gender”).

For sake of simplicity, each *l* will be represented as $[_{\text{Expected(; Agree)}}\text{Phon}_{\ =/+\text{Expect}}]$ as in (14):

(14) $[_{D}\text{the}_{\ =N}]$, $[_{N;\ \text{num.pl}}\text{dogs}]$, $[_{T}\text{barks}_{\ =D}]$

[4] As in MGs, lexical items could be specified both for phonetic (*Phon*) and semantic features (*Sem*). In e-MGs, *expectations* (=/+X) and *expectees* (X) correspond to MGs *selectors/licensors* and *selectees/licensees* respectively. *Agreement* features indicate categorial values to be unified (Chesi 2021).

[5] This is the simplest possible implementation. Attribute-Value Matrices, as in HPSH (Pollard & Sag 1994) or TRIE/compact trees exploiting the sequence of expectations (Chesi 2018; Stabler 2013) are possible implementations.

We refer to the most prominent (i.e., the first) *Expected* feature as the Label (*L*) of the item. E.g., the label *L* of “the” will be *D*, while the label of “barks” will be *T*. Similarly, let us call *S* (for select) the first *Expect* feature and *R* the remaining *Expect(actions)* (if any).

2.2 Structure Building Operations

Given l_x an arbitrary item such that $l_x = (P_x, L_x/Exped_x, S_x/R_x/Exp_x, Agr_x)$ we can define MERGE as follows:

(15) MERGE($l_{1(S1)}$, $l_{2(L2)}$) =

$$\begin{Bmatrix} 1, [l_{1(\cancel{S1})}[l_{2(\cancel{L2})}]] & if\ S_1 = L_2 \\ 0 & otherwise \end{Bmatrix}$$

MERGE is implemented as the usual binary function that is successful (it returns “1”) and creates the dependency (asymmetric C-command or inclusion, in set theoretic terms) (10).c, namely [l_1 [l_2]], if and only if the label of the subsequent item (l_2) is exactly the one expected by the preceding item (l_1), namely $S_1 = L_2$. This is probably both too strict in one sense (adjuncts are not properly selected) and too permissive in another (certain elements must agree to be merged). In the first case, I assume that [l_1 [l_2]] can be formed even if S_1 is not $=X$ but $+X$: while $=X$ corresponds to functional selection (in compositional semantics terms Heim & Kratzer 1998), $+X$ corresponds to an intersective compositional interpretation (e.g. adjuncts and restrictive relative clauses). As for the agreement constraint, I postulate an extra (possibly parametrized) condition on MERGE, namely the sharing (inclusion) of the relevant *Agr* features associated to some specific categories.

The auxiliary functions necessary to implement Agreement are AGREE and UNIFY and can be minimally defined as follows:

(16) AGREE($l_{1(L1)}$, $l_{2(L2)}$) =

$$\begin{Bmatrix} 1 & if\ L_1 \land L_2 \in\ P\{Agr\} \rightarrow\ Unify(\ l_1,\ l_2) \\ 0 & otherwise \end{Bmatrix}$$

(17) UNIFY($l_{1(agr1)}$, $l_{2(agr2)}$) =

$$\begin{Bmatrix} 1, a, \forall a{:}\ Agr_1 \forall b{:}\ Agr_2\ a \cap \mathrm{b} & if\ a \subseteq b \\ 1, b, \forall a{:}\ Agr_1\ \forall b{:}\ Agr_2\ a \cap \mathrm{b} & if\ b \subseteq a \\ 0 & otherwise \end{Bmatrix}$$

Unification is simply expressed as an inclusion relation returning true and the most specific feature for any possible featural intersection between l_1 and l_2 *Agr* features[6]. Notice that Agreement is a conditional, parametrized option, that is, it only involves specific categories (possibly specified in the parameter set *P*): if the *L* category belongs to the Agreement set (*Agr*) in *P* for the grammar *G*, unification will be attempted, otherwise agreement will be trivially successful. The fact that AGREE should apply in conjunction with MERGE is straightforward in the D-N domain: in most Romance languages, in which gender and number are shared between the determiner and the noun, we assume that *D* selects *N* (this happens also for intermediate functional specifications, according to the cartographic intuition, Cinque 2002). This is less evident in the Subject – Predicate case, in SV language, where the predicate should select (then precede) *D*. Since the subject is clearly processed (i.e. merged) before *T*, in canonical SV sentences, and it does not select *T*, a re-merge operation should be considered (e.g. case checking). This re-merge (inducing the locality of Agree, *pace* Chomsky 2001) is logically and empirically sound (movement and agreement can be related and parametrized, Alexiadou & Anagnostopoulou 1998). In this case, re-merge must be preceded by MOVE, an operation that stores in memory an item which is “not fully” expected (i.e. there are $exped_2$ features remaining) by the previous MERGE:

(18) MOVE($l_{1(M1)}$, $l_{2(L2)}$) =

$$\begin{Bmatrix} 1, Push(M_1, l_{2(Phon_2=\emptyset)}) & if\ L_2 \neq \emptyset) \\ 0 & otherwise \end{Bmatrix}$$

The definition of MOVE tells us that an item (l_2) must be moved (pushed[7]) into the memory buffer (M_1) of the superordinate item (l_1) if it still has expected features to be selected ($L_2 \neq \emptyset$). Notice that item moved in M_1 is not an exact copy of l_2: the used features (including *Phon*) will not be stored in memory. This definition produces the expected derivation if it applies right after MERGE, that is, once the item l_2 is properly (at least partially) selected; in this case, if l_2 still has *exp(ect)ed* features to be licensed, it must hold in the memory buffer of the selecting item, waiting for a proper selection of what has become the new l_2 label (i.e. L_2). (Re-)Merge is then when agreement will be attempted (i.e. *if* MERGE(l_1, l_2) in §3, should then be interpreted as *if* MERGE(l_1, l_2) $\land$ AGREE(l_1, l_2) *then…* for specific parameterized categories). In the end, the top-down derivation in SV languages would unroll as follows: the subject (a DP) is first

[6] UNIFY(*num*, *num.pl*) = *num.pl*; UNIFY(∅, *num.pl*) = *num.pl*; UNIFY(*gen.f*, *num.pl*) = *gen.f*, *num.pl*, since *gen* and *num* are distinct agree subsets. On the other hand, UNIFY([*gen.f*, *num.sg*], *num.pl*) would fail.

[7] PUSH and POP are trivial functions operating on arrays: insert (PUSH) / remove (POP) an item to/from the first available slot of a stack or a priority queue.

selected by a superordinate item (presuppositional subject position, situation topic, focus etc.)[8] then it gets (partially) stored in the *M* buffer of the selecting item in virtue of the unselected *D* features, then re-merged as soon as a proper predicate, expressing the relevant *T* category requiring agreement (*T* should be included in the parameterized *Agreement*), is merged and properly selects a *D* argument (or it selects a *V* that later selects *D*). The content of the memory buffer is transmitted (inherited) through the last selected expectation, namely when the expecting and the expectee items successfully merge and the expecting item has no more expectations ($R_1 \neq \varnothing$).

If the expecting item has expectations, then the expected item constitutes a nested expansion, and the inheritance mechanism is blocked:

(19) INHERIT($l_{1(M1)}$, $l_{2(M2)}$) =

$$\begin{Bmatrix} 1, M_2 \Leftarrow M_1 & if\ \text{MERGE}(l_1, l_2)\ \wedge R_1 \neq \emptyset) \\ 0 & otherwise \end{Bmatrix}$$

The M buffer of the last selected item that does not have other expectations (namely a right phrasal edge, i.e., $S=\varnothing$) must be empty (i.e., $M=\varnothing$). If not, the derivation fails (i.e., it stops) since a pending item remains unlicensed:

(20) SUCCESS($l_{x(Sx,\ Mx)}$) =

$$\begin{Bmatrix} 1, & if\ S_x = \emptyset\ \rightarrow M_x = \emptyset) \\ STOP & otherwise \end{Bmatrix}$$

Notice that the sequential item must be properly selected ($=S_X$). If this is not the case, the inheritance would transmit the content of the memory buffer of the superordinate phase into the memory buffer of an adjunct or a restrictive relative clause, which clearly qualify as (right-branching) islands. Therefore, the "restrictive" (since feature driven) MERGE definition in (15) seems correct and empirically more accurate than "free Merge" (Chomsky, Gallego & Ott 2019: 238).

3 The Derivation Algorithm

We can now define the full-fledged top-down derivation algorithm which is common both to generation and to parsing tasks (§3.2). Consider *cn* to be the *current node*, *exp* the list of pending expectations and *mem* the ordered list of items in memory. We initialize our procedure by picking up an arbitrary node from *G.Lex* as *cn*. Being *cn* the *root* node of our derivation(al tree) and *w* the array of words we want to produce/recognize, we can define the function DERIVE(*cn*, *w*) as follows:

```
while cn.exp & w
  while cn.mem
    foreach cn.mem[i] in cn.mem
      if MERGE(cn.exp[0], cn.mem[i])
          POP(cn.exp)
          POP(cn.mem)
      else break
  if MERGE(cn.exp[0], w[0])
    POP(cn.exp)
    if w[0].exped
      MOVE(cn, w[0])
    if w[0].exp
      cn = w[0]
      INHERIT(exp[0], w[0])
      SUCCESS(w[0])
    POP(w)
    if not cn.exp
      while !cn.exp & (cn != root)
          cn = cn.father
  else fail
```

Informally speaking, as long as we have lexical items to consume (*w*), we loop into the set of expectations of *cn (cn.exp),* first attempting to Merge items from (*cn.*)*mem* (if any), as in the active filler strategy (Frazier & Clifton 1989), then consuming words in the input (being *w[0]* the first available word). Remember that each word has *exp(ect)ed* features (the first being the label *L*), *exp(ectations)* and *agr(eement)* features. *Cn*s have their own *mem* that can be inherited only by the last expected item, and, apart from the root node, a *father*. The derivation is then a depth-first, left-right (i.e., real-time) strategy to derive a structure given a grammar, a root node, and a sequence of lexical items to be integrated.

3.1 The Complexity of Lexical Ambiguity

Ignoring Parameters, the derivation procedure in §3 should face lexical ambiguity: the same *Phon* in *w[n]* might be associated to multiple items *l* in *Lex* with different features; the default option is to initialize a new derivational tree for any ambiguous item in *Lex*. Given an ambiguity rate *m* in *Lex*, the derivation procedure would have an exponential order of complexity $O(m^n)$. We can mitigate this, either by selecting the element(s) bringing only coherent (i.e. expected) categories (a categorial priming strategy, Ziegler et al., 2019) or to use a statistical oracle, following Stabler (2013), to

[8] We have various options to implement this selection: a specific feature (+focus, +topic, +presupposed etc.) can be added to the relevant item (but this would lead to a proliferation of lexical ambiguity, e.g. [D the …] vs [FOC D the …]) or we assume that certain superordinate items can select specific categories, without deleting them (e.g. [+D ε FOC]). In this implementation, I will pursue this second, more economic, alternative.

limit (or rank) the number of possible alternatives. It is however important to stress that lexical ambiguity is the major source of complexity in this derivation: syntactic ambiguity is greatly subsumed by the lexicon, being the source of structural differences related to the set of categorial expectations processed and to the order in which lexical items are introduce in the derivation. With the strict version of MERGE defined in (15), no attachment ambiguity is allowed, since a matching selection must be readily satisfied as soon as the relevant configuration is created (but see Chesi & Brattico 2018). This is not the case if we would admit "free merge" instead of select/licensors-driven merge: in the first case, admitting that MERGE($l_{1(S1)}$, $l_{2(L2)}$) is possible also if $S_1 \neq L_2$, would produce a syntactic ambiguity which is (exponentially) proportional to the number of items merged in the structure. This is a crucial argument to prefer feature-driven Merge. Notice, moreover, that admitting that re-merge is also possible without proper licensors/selectors, would quickly lead to unbounded unstoppable recursion. This must be prevented if we want to avoid the *halting* problem. Therefore the licensors/selectors option seem to be a more logical, self-contained, solution.

3.2 Generation and Parsing

As far as Generation is concerned, the procedure described in §3 is integrally adopted and it is sufficient to produce the expected sentence with the associated, dependency-based, structural description. As long as the sequence of words *w* is concerned, once a root node is selected, it is easy to imagine a dynamic function, instead of the static ordered sequence *w*, that incrementally proposes items to be integrated, given the history of the derivation or, at least, the last expectation (a sort of structural priming, possibly enriched with semantic features if we add to the lexicon *Sem(antic)* specifications in addition to *Cat* and *Phon* ones).

Notice that the lexicon can include phonetically empty categories; this is not a problem for the generation procedure, that consumes input tokens one by one, and then considers a phonetically empty category on a par with phonetically realized ones, namely each item should be postulated as incoming token to be processed.

From this perspective, the Parsing procedure is minimally different since it must postulate a phonetically empty item, for instance in pro-drop languages, by deducting that the *w* sequence received in input is incomplete/incompatible with specific structural hypotheses. One proposal (Brattico & Chesi 2020) relies on inflectional morphology as an overt realization of unambiguous person and number features cliticized on the predicate, hence doubling the (null) subject. Otherwise, only after a relevant category is selected (with its agreement features) and unmatched by the current input, the empty item could be postulated. This non-determinism is exacerbated by the attachment/selection ambiguity: given $[l_{1\ =/+X}\ [l_{2\ =/+X}]]$, for instance, an incoming item with *X exp(ect)ed* feature that should be merged with l_2 first, according to the derivation algorithm provided in §3, could, in fact, be merged also with l_1, assuming that $l_{2\ =X}$ expectation can be satisfied with an empty item bearing *X* as *exp(ect)ed*. Similarly, an adjunct marked with *Y exp(ect)ed* category could be merged with both l_1 and l_2 in $[l_1\ [l_2]]$ in case of lexical ambiguity ($[l_1]$, $[l_{1\ +Y}]$, $[l_2]$, $[l_{2\ +Y}]$). In this sense, the derivation procedure in §3 is insufficient as a full-fledged parsing strategy and must be integrated with disambiguation routines dealing with the possibilities just mentioned. It is however important to stress that these disambiguation strategies do not alter the general derivation procedure introduced here, which remains the lowest common denominator of Generation and Parsing in e-MGs.

4 Conclusions

The e-MGs formalization proposed here is a simple (parametrized) framework for comparing syntactic predictions directly with human parsing and generation performance evidence. This is possible since the core derivation algorithm is assumed to be the same in both tasks (token transparency, Miller & Chomsky 1963). While there is little to add to implement a full-fledged Generation procedure (see §3.2), as long as the Parsing perspective is concerned, the information asymmetry of this task with respect to Generation requires extra routines to be implemented, in addition to the basic derivation algorithm: lexical ambiguity must be resolved "on-line" and phonetically empty items must be postulated when needed. This creates an extra level of complexity which is however manageable under the same derivational perspective here presented: the core derivation is sufficiently specified to operate independently from parsing-specific disambiguation assumptions which operate monotonically with respect to MERGE, MOVE and AGREE. This is an ideal foothold for metrics that aim at comparing the predicted difficulty not only globally (De Santo, 2020; Graf et al., 2017) but also "on-line" that is, on a word by word basis (Chesi & Canal 2019; Chesi 2021).

Implementation:
https://github.com/cristianochesi/e-MGs

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