On Phrase Structure building: How your theory of labeling gives away your theory of mind

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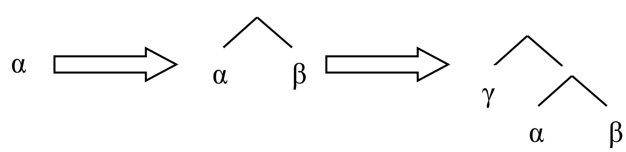
Abstract:

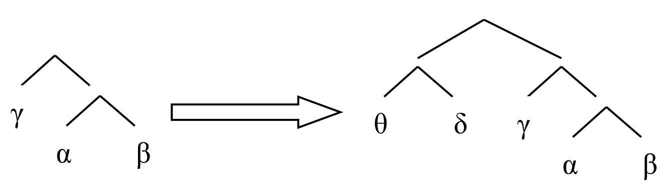
In this work we will analyze some recent proposals about how the result of the application of a generative algorithm is recognized as a unit for the purposes of further computations, and how each correlates, either explicitly or implicitly, with a model of the mind. We will propose, in line with previous works, that a mixed approach to mental computations (including both Markovian and non-linear dependencies) can prove useful at both theoretical and empirical levels when stated explicitly. We will argue that phrase markers include both kinds of dependencies between terminals and non-terminals: labeling requirements in a theory (which, in turn, interact with other conditions on phrase structure, binarity being the most notable) give away the conception a certain theory has about the (uniform or not) functioning of the mind.

Keywords: Labeling; Merge; Unification; Markovian dependencies; non-linear dependencies

1. What is labeling?

A generative grammar for natural language is an explicit formal system (Chomsky, 1965: 4; 1995: 162, fn. 1) based on an algorithm that generates structural descriptions of complex structures made out of atomic elements at the levels of morphosyntax and lexicon. Current developments within Chomskyan transformational version of generative grammar, from Chomsky (1995) on, have led to the proposal of a single, 'free' generative algorithm called Merge, which '*takes objects X, Y already constructed and forms a new object Z.*' (Chomsky, 2013: 40). Needless to say, stipulations aside, X and Y can be of arbitrary complexity, either terminals (i.e., lexical items) or non-terminals built via Merge (i.e., sub-trees), which, in Uriagereka's (2002a) terms corresponds to the distinction between Monotonic (expressible in Markovian terms[1]) and non-Monotonic (non-Markovian) Merge. These options are illustrated in (1) and (2) respectively:

1) 

2) 

[1] Consider that Markov models allow head-tail recursion, insofar as loops can consist of arbitrarily long chains of symbols, linearly ordered (i.e., excluding hierarchy). If this is so, as Uriagereka (2008: 233) proposes, then the Markovian character of monotonic Merge (or "merge to the root") follows straightforwardly.

There are some crucial notions in the previous paragraph: one of them is the 'new object Z' part. Within the Chomsky Hierarchy, an inclusive classification of formal grammars[2] (see Chomsky, 1956), External Merge EM (where X and Y belong neither to the same object nor to each other) is regarded by Uriagereka (2008: 234) as a *context-free* operation, as it creates Z from two any X, Y available in a derivational space, and is thus available for Push-Down Automata, allowing *true recursion*, i.e., center embedding (as opposed to Finite State Automata, which allow only *head-tail* recursion). Notice, however, that this operation can be further decomposed as follows:

3) a. Concatenation (join X and Z together)
   b. Labeling / Projection (form Z)

Such decomposition has been attempted, among others, by Hornstein & Pietroski (2009), under Minimalist assumptions. Of those steps, only the first is context-free, insofar as Labeling requires the algorithm to peer into either X or Y to find categorial features to project (following orthodox assumptions). Thus, Labeling must be as (mildly) context-sensitive as Internal Merge IM, if its context-sensitive nature (in turn, requiring *at least* an extended Push-Down Automata, PDA+ to be implemented) depends on IM *searching* within an already object W to extract / copy X ∈ W and merge it to W (so-called *reprojection*, see Matushansky, 2006) or to Z ⊃ W, always extending the phrase marker (the so-called *Extension Condition*, see Chomsky, 1995; Kitahara, 1997) without modifying it internally. If EM is indeed free and unbounded, as many, including Chomsky (2004), have claimed, then the context-sensitive character of a generative grammar is given by the Labeling algorithm: IM is sensitive to labeled structures ('previously merged structure', Uriagereka, 2008: 234), implying dominance relations. In turn, the Extension Condition (as well as the more recent No-Tampering Condition, Chomsky, 2005) is also label-sensitive: consider that the requirement to extend the phrase marker makes sense only if there is a restriction over X extracted from W to merge Z and project W:

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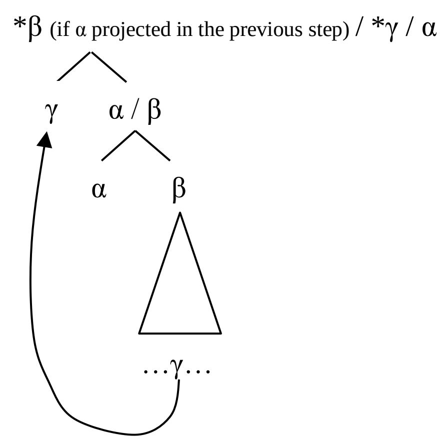


2 When referring to the CH, we will focus on the computational properties of the automata in which the grammars are implemented, and the constructions thereby generated. We will not focus on mathematical linguistics (but see Kracht, 2003 for introduction and discussion), but on the computational properties of the human mind-brain.

Notice that we are considering that only the two most recent elements in the syntactic workspace are plausible to project (an assumption that goes back to Chomsky, 1995; Kitahara, 1997; Uriagereka, 1998, among others): otherwise, labeling possibilities for the matrix object would include all terms of β, including β itself and all syntactic objects it contains, and labeling possibilities for β would also include γ, a deep embedded object within β.

The structure of the paper is the following: section 2 will be devoted to discussion of previous proposals, including Minimalism (Chomsky, 2008, 2013; and *phase-level labeling*, Gallego, 2010) and non-transformational proposals (Shieber, 1986; Jackendoff, 2011). We will take into account computational and empirical consequences of each proposal, focusing on the derived implications for the architecture of the mind. Our main point in this paper is that the algorithm assumed for labeling has deep consequences for the cognitive system (roughly equivalent to 'mind') each theory assumes as the software in which their algorithm applies.

2. Discussion of previous proposals:

2.1 Labeling in the Minimalist Program: Chomsky (2008; 2013)

The Merge algorithm brings up the problem of *labeling*, how to signal headedness and account for endocentricity as it seems to be a pervasive feature of human language (see Adger, 2013 for a cognitively-oriented introduction). Chomsky attempted to solve it with a simple rule: he proposed that there are two kinds of *merge*, *pair-merge* and *set-merge* (Chomsky, 1998: 58). In the former, we are talking about adjunction, which is still a problem in minimalist theory, since no satisfactory theory for their derivation has been yet proposed (that we know of; see Uriagereka, 2005 for a Markovian take on adjunction), insofar as current theories (see, e.g., Hornstein, 2009: Chapter 4) rest on a series of stipulations over phrase markers and the distinction between complements and non-complements in a non-principled way. In those cases, if we *externally pair-merge* α to β, it is always β that projects. Chomsky (2004) has suggested that adjuncts are assembled in a parallel derivational space, and then introduced in the main tree by means of an old mechanism recently revived: a *generalized transformation*, which, simplifying, introduces a sub-tree in a terminal node of another sub-tree, as we have pointed out with non-monotonic operations. Asymmetries between arguments and adjuncts are thus theoretically enhanced in purely structural terms. In *set-merge*, there is some 'requirement' of α which is satisfied by its merger with β (say, argument structure, possibly coded in terms of selectional features), and it is α that projects a label. The labeling algorithm that Chomsky proposes for Merge(*n*), where *n* always equals *two* distinct elements, can be summarized as follows (Chomsky, 2008: 145; also 2013: 43)[3]:

5) i. In {H, α}, H an LI, H is the label

ii. If α is internally merged to β, forming {α, β}, then the label of β is the label of {α, β}.

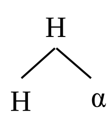
[3] Similarly, Hale & Keyser (2002: 62) claim that "*The label of a syntactic object X is the feature set [F, H], where [F, H] is the entire complement of phonological, morphological, syntactic and semantic features of H, the head of X.*". However, Hale & Keyser contemplate the theoretical scenario in which there is simple upwards percolation of features, without the necessity of there being an [α, H] situation to force labeling.

In addition to this criterion (ultimately, stipulative) to determine how the result of Merge will be interpreted for the purposes of further computations, there is a corollary to (5 i), which was examined by Uriagereka (1998) and, in less detail, Chomsky (1994): if Label is part of Merge, then, the label of Merge (X, Y) is *either* X or Y, no other option being acceptable under Minimalist assumptions. Consider the following scenario, summarizing discussion from the aforementioned sources (see Uriagereka, 1998: Appendix for a first formalization of these possibilities within a Bare Phrase Structure model):

6) Merge ($V_{[+V, -N]}$, $N_{[-V, +N]}$) = {V, N}
7) Label {V, N}:
   a. VP (i.e., Label {V, N} = V)
   b. NP (i.e., Label, {V, N} = N)
   c. Unification ([+V, -N], [-V, +N])
   d. Intersection ([+V, -N], [-V, +N])

The generative orthodoxy has adopted option (a), although only on syntactic basis, not always clear. While (as we will see below) Unification can lead to a crashing representation if, as in this case, feature structures do not match, and the Intersection might be an empty set (thus leading to an empty label, rendering the object non-interpretable); there is no clear reason, beyond theory-internal stipulations, to choose (a) over (b) in (7). Two such sets of stipulations concern, on the one hand, *set Merge*, featuring selection from X to Y or viceversa. In this scenario (corresponding to (5 i)), H projects because it selects α, and that asymmetry is captured in labeling. The asymmetry can be graphed in the following way, using familiar X-bar tree representations:

8)



In computational terms, this implies that the structure {H, α} will be taken as H for the purposes of future operations, including both structure building (Merge) and structure mapping (Move). There are three main problems when considering the MGG approach to Merge + Label:

- Head + head merger
- Non-terminal + non-terminal merger
- Head adverb + non-terminal merger

Why are those situations problematic? Let us analyze each in turn. Consider a simple structure V + Prn., as in Merge(like, it): unless we assume there are extra projections for the pronoun (see Uriagereka, 1998; Lasnik, Uriagereka & Boeckx, 2005: 117, ff. for an antisymmetry-related proposal that assumes a Top-like projection in order to make an LCA compatible phrase marker), the relation in a bare phrase structure is of sisterhood between two lexical heads, that is, {H, H}. As far as we know, this is a situation that (5) does not contemplate, insofar as there is no way to determine (unless stipulatively) which of the two elements is H and which is α (in terms of condition (5 i)), and the reasoning becomes circular (object X is H because it projects, but it projects because it is the selecting H). Chomsky, in discussion with Cedric Boeckx (Boeckx, 2009: 52) makes a strong claim at this respect:

> '*The crucial fact about Merge – the "almost true generalization" about Merge for language is that it is a head plus an XP. That is virtually everything.* (…) *For one thing it follows from theta-theory. It is a property of semantic roles that they are kind of localized in particular kinds of heads, so that means when you are assigning semantic roles, you are typically putting together a head and something. It is also implicit in the cartographical approach. So when you add functional structures, there is only one way to do it, and that is to take a head and something else, so almost everything is head-XP*.'

Two aspects are to be taken into account here: on the one hand, Chomsky is forcing the system to compile with (5 i), adding extra structure (thus, extra empty nodes) when a head-head situation presents (consider, for instance, V+N structures in languages in which D layers are apparently absent, see e.g., Bošković, 2008: even if those theories have been challenged, there is no reason not to take them into account when formulating a generalization this powerful). On the other, the justifications offered for this 'almost true generalization' are exclusively intra-theoretical (theta-roles are properties of heads, instead of, for instance, properties of construals; quite the same is the case of cartographical approaches). While it is true that, should one add functional structure, the resulting situation is H-XP, there is no *independent* justification about why one should add functional structure on the first place.

Going further, notice that condition (5 i) rules External Merge (i.e., structure building) *only* when we are dealing with *monotonic Merge*, but *non-mononotic Merge* is not considered (i.e., Externally Merge X and Y, such that X and Y are independent sub-derivations). Adjunction is thus a problem for the projection system, as Hinzen (2009) correctly points out:

> '*…basically they* [adjuncts] *have never fitted into the apparatus of syntax that minimalism has tried to derive from 'virtual conceptual necessity.' They do not receive theta roles, and do not take part in the agreement system.*'

Given this briefly summarized state of affairs, it is hard to figure out where non-subcategorized elements would be merged, since they are apparently dispensable with and thus are not L-marked (Chomsky, 1995) because they are technically not arguments. Adverbs and adverbial constructions would fall in this category of 'Adjuncts', both syntactically and semantically problematic. There are no PSR in the Minimalist Program, and thus the apparent optionality of adverbs and adverbial constructions and their peripheral character as far as the X-bar schema is concerned was not easily justifiable once the notion of L-marking was left aside after initial Minimalist developments (in fact, Chomsky, 1995 is the only place in which we can find the notion within the core orthodox proposals[4]). When we have Merge (α, β), being α and β heads (say, V + clitic; V + P, etc.), label

[4] Lasnik & Uriagereka (2005: 106) write '*In MPLT* [A Minimalist Program for Linguistic Theory, Chomsky, 1993, reprinted as Chapter 2 in Chomsky, 1995] *Chomsky suggests that A-chains are somehow L(exically)-related to an argument-taking element (e.g., a verb), while A'-chains are not. We wish we could provide our*

choice is completely arbitrary: why should Merge($ire_V + ad_P$) be categorized as V and not P (based on Chomsky's algorithm)? Only L-marking and / or selection stipulations can be summoned to solve the problem. Quite the same happens when we have two non-terminals merging, as in the case of non-monotonic merge of subjects (i.e., DP + *v*'; or merger of DP to T' on subject raising): unless resorting to semantic reasons (e.g., the fact that, if *v* contributes *causativity* to the construal, then it licenses the presence of an initiator argument), there is no *principled* reason to label the resulting object as a *v*P. Chomsky himself recognizes this when claiming that '*There is no more reason for NP to be SPEC-TP than for TP to be SPEC-NP* [in subject raising]' (2013: 42). Notice we are *not* saying that the object *is not taken as a vP* or a *TP* for the purposes of future computations, but that the purely syntactic criterion presented by MGG is not sufficient to reach that conclusion: feature inheritance stipulations (as the ones assumed to justify some C-T relation, and thus guarantee that T will project instead of N when the subject rises to TP; see Chomsky, 2013: 43, ff.) are intra-theoretical, and do not provide an actual explanation (if anything, a re-statement of the problem in different terms). In Chomsky's (2013) interpretation, either feature sharing / inheritance stipulations come into play (for C-T relations, possibly holding also for the *v*-V pair) or one of the non-monotonic objects has to move in order to satisfy antisymmetry requirements (Moro, 2000), or else there is no need to label every syntactic object: neither explanation holds independently of the rich intra-theoretical system of current Minimalism. The situation does not become any simpler when adverbs are considered: assume an event-oriented adverb (i.e., adjunct to VP) or a subject-oriented adverb (i.e., adjunct to *v*P) like 'fortunately' or 'consciously' respectively. Those adverbs are lexical items, in a bare phrase structure theory; thus, they are terminals. Merge (Adv, VP), if Adv is a lexical item, should result on an AdvP containing a VP, according to (5 i), but this is prevented by assigning so-called adjuncts a special role within the system of projection (Chomsky, 1995; see also Hinzen, 2006), a stipulation that is not shared by non-transformational grammars (e.g., Bouma et. al., 2001, section 4). Within the HPSG tradition (see Pollard & Sag, 1994; Green, 2011), for instance, the elements a predicate subcategorized for are represented as a list of features in a lexical entry, called ARG(ument)-ST(ructure), which differs from valence features (SUBJ, COMPL, and SPR –specifier-). Bouma et. al. (2001: 6-7) explicitly say that, whereas the default case is a 1-to-1 correspondence between ARG-ST and valence, it is not always the case. This is particularly relevant for their claim that adjuncts are selected by a lexical head pretty much in the same way complements are. The hypothesis put forth in Bouma et. al. (2001) is that post verbal adjuncts are in the same level as complements (at least, in English). This shows that the labeling algorithm in (5) (which is not actually an algorithm) is stipulative, and does not derive from interface conditions over phrase markers. The picture of labeling in Chomsky's writings (including the very recent 2013 piece devoted to the topic) is far from clear, leaving open the possibility that some objects are not labeled under arbitrary conditions (e.g., successive cyclic Wh-movement, where intermediate steps in Spec-CP unable to meet the wh-criterion, as in Chomsky, 2013: 44). The question of which objects *need* to be labeled (according to MGG) arises, and so does a proposal from *phase theory*, which we will review next.

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readers with an explicit definition of L-relatedness, but we know of none.' While this may overlook proposals like Zagona's (1988), it is true that the notion has been left undefined as far as Minimalism is concerned.

2.2 Phase-based labeling: Gallego (2010)

Stemming from a parametrizable version of *phase theory* (in which *v*-to-T movement, available only in *pro-drop* languages, extends the phase from *v*P upwards to TP via *phase sliding*), Gallego (2010) makes a double proposal with respect to limited domains for syntactic operations:

9) *Phase Condition: Uninterpretable features (uFF) signal phase boundaries* (2010: 51)
10) *Phase-level labeling: The label of K* [a term generated via Merge] *is determined at the phase level* (2010: 19)

The logical consequence of the combination of these principles, which are part of the same formal axiomatic system, is that the label of K is determined at the points where a head bearing [uF] enters the derivation. Gallego, following Chomsky, assumes those heads are C and *v* (based on intra-theoretical assumptions): phases and labels are defined at CP and *v*P.

In our opinion, apart from the highly stipulative nature of the proposal, it turns out problematic in some cases, if labels determine how a syntactic object is to be taken for future computations: consider the case of an ECM construction including an unaccusative V, like (11):

11) John wanted them to go

If we assume the framework of Chomsky (2000; 2008), ECM constructions lack a CP layer, being labeled bare TPs possibly 'defective' in some unspecified sense, insofar as

> '*T manifests the basic tense features* [Tense, Person, and Number] *if and only if it is selected by C (default agreement aside); if not, it is a raising (or ECM) infinitival, lacking φ-features and basic tense*' (Chomsky, 2008: 143)

and we also asume, following Chomsky (2001: 107), that '*neither finite TP nor unaccusative / passive verbal phrase is a phase*', the structure of (11) in terms of phasehood is (12):

12) [P John [P wanted [N them to [N go]]]] (where P = phase; N = non-phase)

If Gallego's labeling condition (10) is to be applied here, we have to assume that, until matrix *v* is merged, the syntactic object [TP them [[T to] [VP [[V go] ~~them~~]]]] is left unlabeled *and* untransferred. If one of the original motivations for phases was the reduction of active objects in the working bench, this is certainly a problematic example, since there is a whole proposition active *go(them)* which is not LF interpretable because it has no label, and cannot be transferred because there is no phase head to trigger the process. We also see that this kind of examples, built using the very same machinery Chomsky has proposed, prove problematic for phase theory, particularly those versions (like Richards' 2007) that aim at a regular P-N alternation: counting all projections in the ECM clause, there is not a single phase (irregardless of what SMT could force). Interface consequences are clear: if the interpretation of N undominated by P is defective because φ-features and semantically interpretable dimensions (like tense) are to be inherited, the whole ECM domain is uninterpretable *per se*, and T is regarded as little more than an Agr projection (with no interpretable dimensions of its own, not even Tense).

The label of the syntactic object is thus undetermined until the merger of a phase head, which posits yet another problem: according to Chomsky's (2008) No-Tampering Condition, phrase markers cannot be modified once completed, operations must always *extend* the tree. However, there are two possible scenarios in the system if we assume (9) and (10):

a) Once matrix *v* is merged, *all projections within the domain of v are labeled*
b) Once matrix *v* is merged, *only the strict complement of v is labeled*

Both options are problematic. If (a) is the option to take, then all phrase markers within Dom(*v*) (using Uriagereka's 1998: Appendix terminology) are tampered with: if this violation of the NTC is allowed, then only a stipulation could ban others (e.g., External Merge to an already closed projection). On the other hand, if (b) is adopted, then all projections *within* the domain of the strict complement of *v* are left label-less. If labels have any reality, they have it at the LF interface (something Gallego himself acknowledges when preferring 'label recognition' to 'label creation'), and render a syntactic object legible for that interface. If a label recognition approach is taken, combined with the assumptions in (9) and (10), the result is that the interface recognizes no label within the domain of the strict complement of *v*, which is labeled VP (assuming that *v* always select V).

While a free Merge system like the one Gallego apparently assumes is not obliged to label at each derivational step (in the 'label creation' sense), the interfaces can peek into the workspace, see what has been assembled, and interpret it in some way (i.e., label it). If they *can*, only a stipulation could prevent them from doing so, insofar as extremely local evaluation (i.e., peeking after each structure-building operation) can result in transfer smaller fully interpretable units, reducing the amount of material in the working memory without the problems of an aprioristic 'every phrase is a phase' approach (see Boeckx, 2010 for a criticism of this position).

More restricted conceptions of phrase structure building, in which feature relations play a major role (e.g., Pesetsky & Torrego, 2007; Wurmbrand, forthcoming) can adapt the criteria in (5) to determine the label of a construction based on a Probe-Goal relation: such is the approach taken by Ceccheto & Donati (2010), in which the label of a syntactic object is provided always by the Probe triggering Merge (a way of re-introducing the concept of selection / sub-categorization), but at the cost of introducing a new stipulation in the formal system. A possibility, then, would be to eliminate labels, which we will comment below.

2.3 Eliminating labels in the Minimalist Program?

As an effort in eliminative Minimalism, Collins (2002) attempted to eliminate labels as they were conceived of, and made use of label-free trees doing away with Chomsky's labeling algorithm[5]. In his view, no operation can make reference to 'maximal projections' or 'intermediate projections',

[5] Seely (2006) follows Collins in his eliminative enterprise (sharing many of his assumptions), but the model he describes does not have enough differences with that of Collins to review it separately. Seely *assumes* that representations are label-free (in Collins' sense), and asks *why* they should be so (2006: 183) in a strongly derivational syntax.

since those terms only have sense within traditional X-bar theory. Collins' argument is that even though lexical items may have 'categorial labels' based on the feature matrices [+/- N] and [+/-V], those categorial features *do not project*: his conception of *labels* (which he replaces by the very similar notion of *locus*, a similarity he himself acknowledges; 2002: 48) is not very different in this respect to that of Ceccheto & Donati (2010), who consider that a label is a set of features that percolate from a head, and trigger further computations. Similarly, Collins focuses his criticism on four areas on which labels have been considered necessary:

• X-bar Theory

• Selection (in terms of subcategorization for lexical features)

• Minimal Link Condition (applied to Target-α, for example)

• PF interface (e.g., phonological phrasing only apply to XP)

Ceccheto & Donati (2010) add a subset of Binding Theory, Principle C, which has been dubbed anomalous for decades now (see Lebeaux, 2009 for a recent perspective on Principle C's special status). In their perspective, a tension between two probes and a single goal can explain Principle C effects (a topic we will not discuss here).

According to Collins, all reference to *labels* in the traditional sense can be dispensed with if we take into account four 'syntactic relations' that can hold between lexical items, ill-formations being mainly a matter of violations of a reformulated Minimal Link Condition, insensitive to labeling (Cf. Chomsky, 1995):

• Theta (X, Y): X assigns a theta role to Y

• EPP (X, Y): X satisfies the EPP feature of Y

• Agree (X, Y): X matches Y, and Y values X

• Subcat (X, Y): X subcategorizes for Y

However, Collins' model can be proved wrong if one can demonstrate that those operations either do not exist or are not triggered by features[6]. For instance, Author & X (2013) have provided an interface-based explanation for subject-raising (taking into account the notions of theme and grammatical salience) without resorting to an EPP feature: EPP (X, Y) can thus be eliminated. Hale & Keyser's (2002) configurational theta-theory (also developed by Mateu Fontanals, 2002) takes care of Theta (X, Y), shifting the burden to the LF interface and putting more stress on semantic construal. Agree and Subcat simply do not arise as operations in a free Merge system: if syntactic objects are built in order to comply with Agree requirements (probing up or down, does not make a

[6] At this respect, Seely's model is harder to falsify, insofar as it claims that *labels are syntactically inert* (2006: 184). If they are inert, then the model does not depend on the four syntactic relations mentioned above, and a counterargumentation (within a mild BPS framework) should have to follow a different path. However, the *computational* consequences of Seely's model are just the same as Collins'.

difference), then Merge is not free, but stpulatively constrained (insofar as there is no independent evidence for the existence of features in the Chomskyan sense as primitives of language structure). Feature-rich proposals like Ceccheto & Donati propose that:

> '*Once a label is defined as a subset of the features of one of the two merging objects, the quest for simplification argued for by Collins can be satisfied*.' (2010: 241)

Of course, we have to note that there is no reason *why* a label is to be defined that way (for a related proposal about Merge being triggered by subset relations between feature structures, see Di Sciullo & Isac, 2008), nor is there, in our opinion, compelling evidence that labeling is part of the theory of phrase structure instead of the theory of the syntax-semantics interface.

We are omitting some proposals, insofar as we consider MGG has provided variants of the already reviewed theories instead of alternative frameworks. Provisional conclusions are the following:

13)

a) The notion of *labeling* is defined only in *syntactic* terms, without reference to the role they play at the interfaces, or whether they might be defined at the interpretative components.
b) Stipulations over labeling are intimately related to stipulations over X-bar theory (e.g., Hornstein's 2009 claim that there is an operation *concatenation* which is linear, and it is labeling that counts as the central innovation in UG –Hornstein, 2009: 55), including *endocentricity* and *binarity*. There is no labeling algorithm for Merge(X, Y, …*n*) in current Minimalist theorizing.
c) The theories we have reviewed (and those we have not, including Chomsky's 1994 original presentation of Bare Phrase Structure) rest on the assumption that syntactic structure is *homogeneous*: constituency is always hierarchical, always recursive, and always binary; and such a grammar can be implemented in a *uniform* automaton. In other words, these theories impose a common structure to the mind based on its computability capacities, which are restricted by the formal properties of the generative algorithm. The consequence of the uniformity we have just noted is that a level within the Chomsky Hierarchy *does not* presuppose the lower levels: structures are modeled upon a template (in the case of MGG, X-bar theory) which is inflexible. Therefore, as we will see in section (3) below, mixed dependencies within a syntactic object cannot be accurately modeled[7].

In the next section we will review the algorithm used by non-transformational models, to the extent that it is based on different assumptions about the relation between feature structures within syntactic structures.

[7] To be fair, some critics of the Minimalist program and its computational assumptions also fall in this category. Consider, for example, Bod (2013), who claims that 'language knowledge is hierarchical [and] language use is sequential'. Notice that both objects, use and knowledge, are analyzed uniformly, without there being a possibility licensed by the theory that there are sequential dependencies in language knowledge or that there might be hierarchy in language use (e.g., embedding in adjacency pairs).

1.4 Unification instead of Merge: Shieber (1986)

The formalism put forth by Shieber, and adopted by HPSG, LFG, and other non-transformational grammars, is heavily based on the concept of feature structure (which, although extensively used in Merge-based systems, e.g. Pesetsky & Torrego, 2007; Di Sciullo & Isac, 2008, is not a *necessary* component of the generative algorithm). In fact, it does not apply to undetermined X and Y objects, but, by definition, applies to *feature structures*, which are defined as a partial function of *features* (*dimensions*, in Minimalist syntax) to *values*: for instance, we can have a mapping from the feature [person] to the value [third] (which is a partial function insofar as there are other possible values), as in the following example:

14)
$$\begin{bmatrix} \textit{cat}: & \textit{NP} \\ \textit{agreement}: & \begin{bmatrix} \textit{number}: & \textit{singular} \\ \textit{person}: & \textit{third} \end{bmatrix} \end{bmatrix}$$

Such a structure is abbreviated as D_{NP3Sg}. Feature structures vary in their specificity, and in the number of features they contain (here, we have only *categorial* and *agreement* features, but different formalisms have adopted more, including specifications for grammatical functions). Unification applies to feature structures in the following way (Shieber, 1986: 14):

15) In formal terms, we define the *unification* of two feature structures *D*' and *D*' as the most general feature structure *D*, such that *D*' ⊆ *D* and *D*' ⊆ *D*. We notate this *D* = *D*' ∪ *D*'.

Some further clarification is necessary here, as the terminology used in Unification-based grammars does not always coincide with that used customarily in mathematical logics. Within Unification grammars, ⊆ is used to symbolize a *subsumption* relation between feature structures, in which a feature structure, abbreviated D, contains *part* of the information of another D', such that D' ⊆ D. In more complex terms, the concept of *subsumption* is based on that of *dom(D)* (the *domain* of a feature structure, namely, the features it includes, regardless their mapped values), such that D' ⊆ D *iff* ∀(*x*) such that *x* ∈ *dom*(D'), *x* ∈ *dom*(D). A more concrete example will clarify the differences between Unify and (Chomskyan) Merge (taken from Jackendoff, 2011: 276):

16) a. Unification of [V, +past] and [V, 3 sing] = [V, +past, 3 sing]
(not *[[V, +past] [V, 3 sing]]*, as with Merge)

b. Unification of [VP V NP] and [V, +past] = [VP [V, +past] NP]
(not *[[V, +past] [VP V NP]]*, as with Merge)

We can recognize three possible results of the operation, based on Shieber (1986: 15):

- Unification *adds* information (e.g., feature structures are not identical, but compatible)
- Unification *does not add* information (e.g., feature structures are identical)

- Unification *fails* due to conflicting information (e.g., same features, different value)

Thus, while Merge could be formulated in such a way that derivations *must* be counter-entropic (that is, the informational load for the interfaces is always increased), this is only *one* of the possibilities with Unification, which makes the derivational dynamics, in our opinion, more interesting (insofar as the computational consequences of each possibility have to be taken into account at each derivational point, if Unification is to be implemented in a derivational model). Jackendoff claims that Merge can be regarded as a particular instance of Unify, in which feature structures are reduced to two, in the following way:

17) Merge (X, Y)
Unify (X, [*x*, *y*]), being [*x*, *y*] a feature structure = [X, *y*]
Unify (Y, [X, *y*]) = [X, Y]

However, this reduction of Merge to Unify seems highly stipulative, and based only on labels. Notice that the important factor here seems to be to maintain the label that would be obtained via Merge (e.g., Unify(V, N) should result in a feature structure with a categorial specification V or VP). It is not clear, also, why one-step Merge should be replaced with two-step Unification, and which computational advantages might that bring.

The standard presentation, however, sets focus on issues that are neglected from an orthodox Minimalist stance, most importantly, the inclusion of the notion of *information* when considering structure building. While we have indeed claimed that Merge *could* be expressed in such a way that structure building operations increase information, it is also true that there is no definition of 'information' within MGG, and structure building operations are triggered purely by syntactic means (e.g., feature checking / valuation). The three possibilities Shieber recognizes are, in our opinion, good candidates for interpretative procedures, if the interfaces can access the workspace in which operations apply.

Consequences for the structure of representations are also interesting, particularly if we consider that the computational system in charge of generating (16 a) might not be context-sensitive to generate (16 b): a Merge-based system, according to Jackendoff's account (with which we agree), does not recognize that [V] in the structures [VP V NP] and [V, +past] can be tokens of the same object, thus assigning a new feature to [V] (Tense) and projecting a value (+past) to it. A Unification-based grammar is thus *at least* a context-sensitive grammar, including as subsets both context-free and Markovian grammars, provided it is more flexible than a Merge-based grammar (taking Merge in the MGG sense). The corresponding computational system is, according to Uriagereka (2012: 230-231), an extended Push-Down Automaton (PDA+) which can operate locally within a linear input, stocking portions of information in a limited memory. However, it is not clear whether Unification allows mixed dependencies within feature matrices, thus 'jumping' from one grammar type in the Chomsky Hierarchy to another, a factor we think is crucial for a model of the mind.

The scenario we will present goes along these lines: given the fact that syntactic dependencies are not uniform, the computational system that creates and interprets those dependencies cannot be uniform either. Thus, while it might be the case that

> '(…) *a PDA* [Push-Down Automaton] *for merely CF* [Context-Free] *systems is 'too little', while an LBA* [Linear-Bound Automaton] *for fully CS* [Context-Sensitive] *systems is 'too much'*' (Uriagereka, 2012: 231)

insofar, as Joshi (1985) claims, natural language grammars are *mildly* context sensitive (see also Michaelis, 2001 for a strictly logical analysis of Minimalist grammars); we think there is evidence pointing to the possibility that natural language grammars are not *uniform systems*. Thus, for instance, Chomsky's (1957) alleged proof that finite-state grammars are inadequate suffers from the assumption (always implicit) that if a grammar is not good for a *subset* of constructions S ⊂ NL, it does not apply to *any* part of NL (see Pullum, 2011 for extensive discussion of the mathematical framework of *Syntactic Structures*, and the lack of a 'sound mathematical argument' for the case against Markov models for NL; and Kornai, 1985 for a defense of –uniform- finite state models for natural languages).

After this review of past proposals, we will now present the system of structure building and projection we argue in favor of. Before going directly to our proposal, we will review some antecedents in which we have based our theory, to point out similarities and differences.

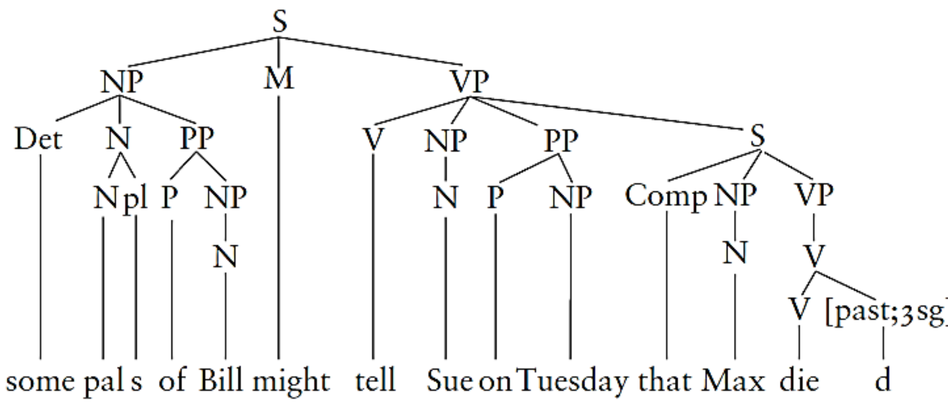
3. A quantum system of projection:

In this section we will expose the main thesis of our paper: if the labeling algorithm a theory proposes gives away (at least part of) the theory of the mind or computational component in which that algorithm applies, the shortcomings of the theories revised above have impact on the computational possibilities they license for a mind. What exactly is a 'quantum system'? In the sense in which we have been working the concept in previous works, a quantum system is different from both a Markovian and a PDA+ insofar as it allows structure to remain in an 'uncertain' state until transferred to the interpretative components: in this system, *category, case, theta role,* and, possibly, *labels* need not be determined at the derivational point in which the relevant unit is inserted, but they are read off configurations *after* transfer to C-I, that is, at LF. Moreover, all those dimensions allow more than one possible outcome, and if this is so, the only non-stipulative scenario (as far as we can see) is to assume that *all outcomes are possible states of the system prior to Transfer(LF)*. We will argue that, contrarily to MGG, dependencies between constituents are not uniform (cf. (13 c)), but we can find constructions for which binary Merge and Labeling would be inadequate, even *within* finite-state (i.e., monotonic) objects. We will focus on *iteration*, *coordination*, and *adjunction* as the relevant empirical phenomena to show mixed dependencies, and propose a more flexible and dynamic approach to deal with them. First, we will review some antecedents for our proposal, which consider the limitations of Kaynean strictly binary trees (Kayne, 1984, 1994) and explore alternative phrase structure theories.

3.1 Culicover & Jackendoff (2005): Flat structure

The Simpler Syntax hypothesis postulates that syntax is a minimal and optimal mapping between form and meaning. As a result, meaning is to be read off directly from the syntax, and there is no place for hidden levels: the theory is not only non-transformational, but also monostratal. The theory of phrase structure adopted by this model, in which syntactic mechanisms are impoverished (in relation to MGG) is simplified so that, without losing empirical adequacy, there is no extra-structure assigned to a construction. This model explicitly argues in favor of *n*-ary branching, allegedly compatible with recent ‘psycholinguistic research’ (2005: 107). Syntactic representations are dissociated from phonological and semantic structures, which are all *parallel* (Jackendoff, 2002), and include only formal features, including categorial specifications. A sample representation, provided by the authors, is the following (Culicover & Jackendoff, 2005: 110, (2 c)):

18)



The authors characterize the representation in the following terms:

> ‘*A number of characteristics mark these structures as ‘flat’ in our sense: (a) there is* ***no hierarchical distinction*** *in the NPs in* […] *(2c) between the attachment of the Determiner and the other complements and adjuncts; (b) the adjunct on Tuesday in (2b)* [and (2c)] *is likewise a sister of the verb and the argument NP; and (c) the lower clause in (2c) has no special Infl or CP nodes.*’ Culicover & Jackendoff (2005: 110. Our highlighting)

Their structures are *n*-ary, ‘flat’ in the relevant sense. Each node dominates as many nodes as elements depend semantically on the head of that node: VP dominates directly V, NP, PP, and S, all constituents traditionally ‘governed’ by V. The cut with traditional X-bar theory is not complete, though: each phrasal node has a single lexical head, all other dominated elements being maximal projections or functional / grammatical material (inflectional morphemes, complementizers, auxiliaries); however, unlike GB X-bar theory, there is no XP/X’ iteration for phrasal adjunction: there is no syntactic distinction between arguments and adjuncts in the syntactic representation (although there is at the level of the semantic tier, following Jackendoff, 2002), nor is *adjunction* a phrase structure building operation within the framework. With respect to *n*-ary branching, the authors, while acknowledging conceptual advantages for binary branching, assume that, even if 2 is the simplest possibility, it does not mean 2 is actually the case (cf. Collins, 1997, and much related work): phrase structure does not derive exclusively from conceptual simplicity (or, as Chomsky sometimes claims, 'virtual conceptual necessity'), but also from empirical requirements. We will analyze cases in which the semantics of an expression (accepting there is some sort of mapping, opaque though it might be) require more than binary branching, without precluding the possibility for binary Merge.

Computationally, the consequences of adopting a single template for branching (which we have partially sketched above) are introduced by Culicover & Jacnekdoff (2005: 113):

> '*One might wish to argue that binary branching is maximally simple on grounds of Structural Uniformity. The argument would be that, first, there are many relations that are binary, and second, we would gain maximum generality by assuming that all relations are binary. However, since everywhere in the universe as well as everywhere in language there will be binary relations, it would follow from this reasoning that only binary relations exist everywhere. It is difficult to see the value of such reasoning, unless it were to turn out that there were positive empirical consequences of generalizing binary relations uniformly, and doing so required no additional complications of the theory. To our knowledge this has not been demonstrated for language, let alone in general.*'

Almost any complex formal object can be modeled in terms of binary relations, from abstract patterns of plant growth to the Fibonacci or Lucas sequences, via an L-grammar (Prusinkiewicz & Lindenmayer, 1991; Uriagereka, 1998); moreover, other kinds of generative devices (e.g., *concatenation* interpreted as *n*-ary addition) can also give us mathematical 'monsters' like π, decomposing multiplication and division in series of additions (with positive integrals for multiplication and negative integrals for division). However, this does not mean that the (computational) *nature* of the object is itself binary, something we can see in linguistic objects if assuming derivations are semantically motivated (in a related vein to the Simpler Syntax hypothesis, but strongly derivational).

Psycholinguistic arguments in favor of binary branching are also discussed. The arguments amount to the following:

19) a. <u>Learnability</u>: given a structure [X_0 XP YP], binary labeling makes it easier for the learner to identify heads and complements, according to Haegeman (1992). However, the argument in favor of binary branching is actually a two-part argument: first, branching is uniform in all syntactic objects. Second, that branching template is binary. We have pointed out that this amounts to saying that the mind has only one option for computation, which is unlikely given the variety of stimuli it has to process. Culicover & Jackendoff (2005: 114) discuss samples of visual sets and musical phrases as examples of head-less structures, which directly derive label-less phrases. Taking 'syntax' in a wide sense (as *structure*, not simply as *linguistic structure*), we fully agree with Culicover & Jackendoff in that '*Binary Merge is nothing but a degenerate one-dimensional version of n-ary grouping*' (2005: 114), and there is no principled (beyond LCA-related stipulations, see Kayne, 1994) or empirical reason why syntactic representations are actually 2-D structures, be them binarily-branched or not.

b. C-command, binding, and unambiguous paths: relations of constituent dependency are (apparently) simplified when the path from α to β is the only possible, a situation guaranteed in a binary-branched tree. Thus, anaphors and pronouns (with particular focus on the former) are sure to be linked to their antecedents at LF, from Reinhart (1983) on[8]. However, while the data proposed by Kayne (1984) in favor of binary branching is consistent with the template, it neither *requires* it nor does it suffice as a *proof* that binary branching is the case. Apart from the NP-structural considerations Culicover & Jackendoff (2005: 116), we add the caveat that if in a double object construction both objects were in the same domain (as in Larson's account, DO and IO appear within the VP as Spec- and Compl-), binding of reflexives and crossover effects should be possible (because relevant objects are equidistant, from a structural point of view; see Chomsky, 1995), but they are banned:

20) a. They showed Mary$_i$ the picture of herself$_i$
b. *They showed a picture of herself$_i$ to Mary$_i$
c. *They gave her mother$_i$ Mary's books$_i$

Furthermore, the impact of heavy NP-shift on binding is not explained in a theory without D-structure, except by stipulating LF covert movement. Consider, for instance, (21), discussed by Culicover & Jackendoff (2005: 119):

21) John showed to Mary$_i$ herself$_i$ as a young girl.

Idioms, and other 'syntactic nuts' (using the term of Culicover, 1999) are taken as alternative empirical evidence against uniform binary-branching representations by Jackendoff (2011), who assumes the Simpler Syntax hypothesis in order to propose alternative minimalist visions of language.

3.2 *Lasnik & Uriagereka (2011); Lasnik (2011); Uriagereka (2012): Markov models revisited*

The inquiry about the nature of the computational system underlying human language was somehow revived, within MGG, by Howard Lasnik and Juan Uriagereka. Lasnik (2011) addresses Markovian properties of 'lower level syntax', which had already been spotted by Chomsky & Miller (1963), under the denomination 'true coordination':

22) The man comes/The old man comes/The old old man comes

For sentences like (22), a phrase structure grammar of the kind Σ, F (Σ a finite set of initial strings and F a finite set of rewriting rules) like the one argued for in Chomsky (1957) (to which we will come back below), imposes too much a structure over the adjective stalking, assuming a uniform system of binary projection. Chomsky himself (1963: 298) recognizes the structural overgeneration of phrase structure grammars:

[8] Notice, however, that binding relations had been captured by Ross (1967) via a combination of linear order and command, without appealing to binary branching.

'*a constituent-structure grammar necessarily imposes too rich an analysis on sentences because of features inherent in the way P -markers are defined for such sentences.*'

Curiously, there was no attempt within MGG to improve the phrase structure engine in order to include Markovian dependencies, but these examples were increasingly overlooked from the '80s on: the arousal of X-bar structure (Chomsky, 1981; Stowell, 1981), and its *binary branching* requirement (Kayne, 1984) directly excluded Markovian dependencies from the picture. Minimalism's Merge operation maintained the essentially binary character, 'deduced' from apparently independent principles like antisymmetry (Kayne, 1994, 2011; Di Sciullo, 2011) and feature valuation operations (Pesetsky & Torrego, 2007; Wurmbrand, forthcoming).

Lasnik (2011) acknowledges the problem imposing 'too much structure' if a uniform 'moving up' in the Chomsky Hierarchy is performed. Even after acknowledging the problem of imposing extra structure on a syntactic object, Chomsky & Miller (1963: 304) insist on the binary character of phrase markers:

'*The basic recursive devices in the grammar are the generalized transformations that produce a string from a* ***pair*** *of underlying strings.*' (Our highlighting)

Lasnik proposes to weaken the binarity requirement so that the structure building algorithm incorporates a generalized transformation mechanism that maps *n* phrase markers into a new phrase marker (see also Chomsky & Miller, 1963: 299), which would yield the required flatness for Markovian dependencies. In the same line, Lasnik & Uriagereka (2011) summarize the computational properties of the grammars in the Chomsky Hierarchy while acknowledging that portions of natural languages display Markovian behavior. The upper limits of finite state grammars are found in discontinuous dependencies, better formalized these days. Thus, a finite state grammar, being purely linear (and devoided of memory) could not formalize the relation between both instances of *what* in sentences like (23) (~~strikethrough~~ represents, as usual, non-pronounced occurrences):

23) What did you buy ~~what~~

Lasnik & Uriagereka (2011: 42) make a very interesting point with respect to Chomsky's argument against finite-state models:

'*It is an interesting empirical question whether, in I-language terms, a 'more inclusive' description entails abandoning a 'less inclusive' one, when the meaning of 'inclusiveness' is less obvious in terms of a generative procedure.*'[9]

Discussion below will clarify why our answer to this problem is 'no', current PS models (based on binarity requirements imposed by antisymmetry, as in Kayne, 1994 and related work; or

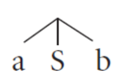
[9] Chomsky (1959: 143; Theorem 1) defined the relation of inclusiveness between grammars by means of a theorem surprisingly *not* followed by a detailed proof referring to natural languages (as would be expected after such a strong claim), and that relation has not been revisited within orthodox generative grammar in later years.

considerations about computational complexity, as in Chomsky, 2013: 40, fn. 20, and his definition / characterization of the generative operation Merge) are ‘too powerful’ to handle what Lasnik calls ‘lower-level syntax’, that is, local, non-hierarchical, purely linear dependencies based on adjacency (as in iteration and coordination). However, non-local dependencies can easily be modeled by PS grammars, as Lasnik & Uriagereka (2011) claim:

> ‘*The descriptive advantage of Post-style PS grammars, as compared to finite state grammars, is that PS grammars can pair up things that are indefinitely far apart, and separated by dependencies without limit. The way they do that is by introducing symbols that are never physically manifested: the non-terminals.*’

Thus, extra-structure comes automatically, in the form of non-terminals. However, the claim that ‘PS grammars can pair up things that are indefinitely apart’ seems a bit too strong to us. In pure formal terms, it is correct, but it does not apply to natural language: locality conditions are too pervasive to be overlooked in the ‘design’ of a formal model for natural language. Thus, and paraphrasing Rizzi’s (2009) Relativized Minimality, X and Z can be paired (i.e., a dependency between X and Z can be established) if and only if there is no intervenient Y. Moreover, structural distance (the criterion to determine how ‘far apart’ X and Z are) is also to be relativized within a MSO model, in which only portions of a derivation are accessible at a time. Locality (including dependencies established within command units, phases, or any other locality-inducing domain) was originally based on computational efficiency and maintaining as little material in the active workspace as possible (Chomsky, 2000; before phases were defined exclusively in terms of feature-checking domains, see Gallego, 2010; Chomsky, 2008 among others). The computational adequacy of the quotation above depends on the capacities of the hardware: unlimited structure requires unlimited working memory (thus being on the Turing-machine stage of the hierarchy), but unlimited working memory is not a feature of human minds. This has an immediate consequence for phrase structure: only phrase markers complying with (24) are possible

24) The following is a parseable phrase marker



If and only if S = n non-terminals, where $n < \infty$

The condition may seem trivial, but it is not if we seriously consider the possibility that the human mind works *uniformly* like a Turing machine, having an unlimited memory tape. Lasnik & Uriagereka claim that ‘*there is no dispute within generative grammar with regards to the significance of this sort of structure*’, which is correct, but whether that sort of structure provides an exhaustive characterization of the phrase structure of natural languages is an empirical question; the nature and characteristics of the computational engine that generates and interprets those structures is another. In our opinion, both have been overlooked in recent MGG. Lasnik & Uriagereka (2011) have great merit, in our opinion, insofar as they propose (even though not operationalize) that ‘*what we need should be, as it were, ‘dynamic flatness’. But this is the sort of concept that sounds incomprehensible in a classical computational view, while making sense to those for whom syntactic computations are psychologically real*’ (2011: 21)

We will attempt to provide a fuller explicitation of such a dynamic phrase structure model, in which Markovian dependencies and non-Markovian dependencies are equally available, each ‘activated’ according to need (cf. the example regarding multiple geometries below). We crucially assume, as Lasnik & Uriagereka do, that *syntactic computations are psychologically real*, and, what is more, the properties of model grammars must depend on the computational properties of the neuro-cognitive substratum.

3.3 Excluding (pure) Markov models, including Markovian dependencies: binary labeling, n-ary branching

Let us experiment with the possibilities a freer and dynamic phrase structure component could give us. We will now spell our provisional assumptions out, in order to make a tentative proposal. Assume the following scenario:

- Labels are not *drawn* from a set (Cf. Adger, 2011) but *recognized* at the semantic interface (Gallego’s 2010 ‘label recognition’): a label is the way of encoding diacritically how a complex unit is to be interpreted for the purposes of further computations.

- There is no *a priori* ‘bar-limit’ (Cf. Jackendoff, 1977 with three bars; Bresnan, 1976 with five; Chomsky, 1986 with two), that is, a label can be recognized (and ‘percolated up’) for as long as it is necessary.

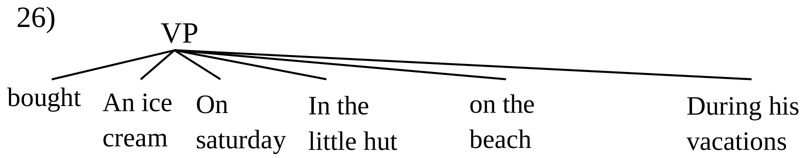
- Merge is reduced to *n*-ary *concatenation*, which takes

If both our assumptions turn out to be correct, which would be the most minimalist scenario, then merge can manipulate *n* objects of arbitrary complexity and maintain a label for as long as the recognition system requires so. Consider:

25) Juan [compró un helado [el sábado] [en el puestito] [en la playa] [en sus vacaciones]]
John [bought an ice-cream [on Saturday] [in the little hut] [on the beach] [during his vacations]]

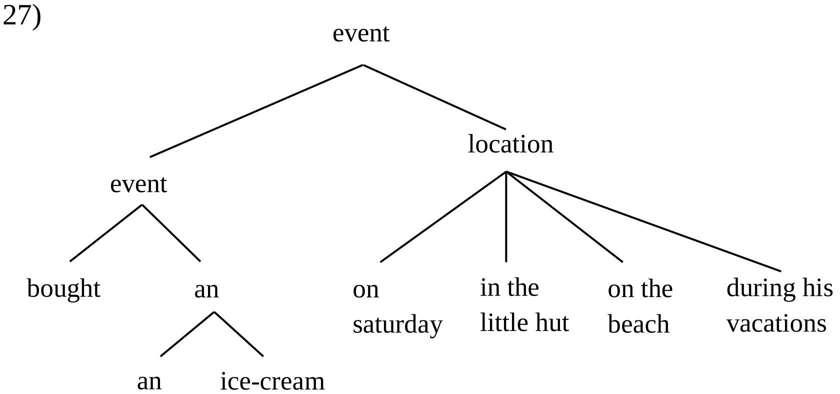
Each square bracket signals a locative domain, therefore, a single labeled node VP dominating five branches (including the complement) should be enough, as in (26):

26)



In (26) we have a term K = VP, including a head V determining the label, and a set of sisters, without distinguishing arguments from adjuncts (quite in the line of HPSG and Simpler Syntax). However, this labeling procedure is not context-sensitive enough to separate the head from non-heads (in semantic terms, if the whole constituent is interpreted as an event, the head should be an eventive entity, grammaticalized as V). Moreover, even though the 'adjucts' all convey locative information (either in space or time), [an ice-cream] conveys a completely different kind of information, related to the limitation of the extension of the event [buy] via an affected object. The differences in interpretation might also give us a clue about the procedure used to assemble each complex unit: locative complements, without there being any scope relation among them, form a Markovian structure, assembled in a workspace X, whereas the relation head-affected object, derived via monotonic merge, can be derived in parallel in workspace Y (recall that monotonically merged structure can be expressed within the limits of a finite state grammar, according to Uriagereka, 2012). Non-monotonic Merge can then unify both structures, to give the complete picture at LF *after* transfer (if monotonic units are Spelled-Out independently, assuming Uriagereka's 2002a Multiple Spell-Out model). Furthermore, the affected object has a hierarchical structure of its own, with the determiner having scope over the conceptual content, therefore delimiting extension and providing referentiality (see discussion in Author, 2012). A further refinement of (26) could be, thus, (27); where the labels indicate specific LF-relevant information:

27)



The representation is read off at the interface as an *event*, delimited in extension by a sortal entity [an ice-cream] (perhaps a generic delimitative label), and including a number of locative specifications, subsumed under a single label Loc. The question now is why the LF interface should recognize those labels: in our opinion, the answer is given by the computational properties of the parser, which is (at least mildly) context-sensitive.

We see that we have a mixed phrase marker, in which there is a hierarchical relation between [an] and [ice-cream], binarily merged; and non-scopal relations among the locative elements. We interpret this as a proof that there are at least two kinds of labeling algorithms:

28) a. Label(S), S a syntactic object, where all elements belonging to S convey the same kind of information

b. Label(S), where elements belonging to S differ in their semantic contribution

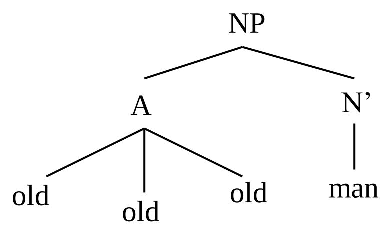
Let us see some examples:

a) <u>Iteration:</u>

29) Sie ist sehr sehr sehr schön
30) The old old old man
31) The man was [old, tired, tall…] but [friendly] (Lasnik, 2011: 358)

In these cases, we cannot say that one instance of the A takes the others as arguments, as a binary branching traditional X-bar theoretical representation would entail. Nor do we need functional projections (Cinque's 1998 FP, for instance) if we allow the system to concatenate those As together and label A (or AP), insofar as their contribution to the interface representation is the same. Taking these considerations into account, the representation Lasnik (2011) assumes is the following:

32)



The question is: why stop labeling A when iteration finishes? That is, unless we come back to criterion (5 i), assuming the bar level proposed by Lasnik is not really there, and we take it to be an instance of an {α, H} merger (α = A; H = N); it would seem that the problem is always the same. However, introducing semantic considerations on labeling could help us solve the problem. Taking (25) into account, as a description about the possible labeling situations we can find, let us make a suitable generalization, which can be taken as an interpretative procedure in a mildly context-sensitive grammar:

33) Label(S) depending on the information conveyed by all elements belonging to S:
    a. If all elements belonging to S convey the same type of information, maintain the label for as long as elements that enter the derivation convey that same type of information;
    b. Change the label otherwise

Notice that condition (27 a) tells us nothing about the branching characteristics of S: it can be either monotonic or non-monotonic. That is, we can be dealing with sequential steps in a monotonic derivation or a single step merging *n* elements conveying the same kind of information (e.g., locative). Let us see what happens when we have *n*-ary Merge involving different kinds of elements. Consider the following finite-state derivational scenario:

34) Merge (α, β, γ) = {α, β, γ}

In the Narrow Syntax, everything would be fine, since Merge is blind and NS is *not an interpretative component*. But, at the semantic interface, problems would arise. Let us assume that α = √ and β and γ are procedural / functional categories, say, D and T respectively.

35) Label {√, D, T} = ??

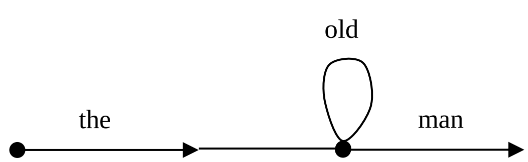
Having two procedural categories results in crash at the semantic interface, as there is no way of labeling a structure where two elements could 'guide' the interpretation in different directions (namely, a sortal entity and eventive entity readings). The same would happen if the numbers are changed, say, two roots and one procedural category: even if we think that one of those root may be 'categorized' in a local relation with the procedural node (V if the procedural element is T; N if the procedural element is D; see Author, 2012 for discussion), there would still be an uninterpretable element, namely, an uncategorized root that cannot be assigned an interpretation at LF because of its drastic semantic underspecification (see, among others, Panagiotidis, 2013). Taking these caveats into consideration, the derivation of (32) would go along the lines of (36):

36) Merge(A, A, A) = {A, A, A}
Label {A, A, A} = {A}
Merge(N, {A}) = {N, {A}}
Label {N, {A}} = {N}

Notice that all adjectives convey the same kind of information, if we accept localism as a suitable account of the nature of adjectival predication: all adjectives (either individual-level or stage-level) are abstract locations, involving the incorporation of a root on a prepositional node (Mateu Fontanals, 2002: 24, ff.). However, N does not convey locative information, but sortality: once the N terminal is merged, condition (33 b) predicts the change of label.

How can we be sure that the iterative pattern in (29-31) is actually Markovian? For starters, it *can* be expressed by means of a finite state grammar, and, if such a simple computational procedure is enough, why attempt to go up in the Chomsky Hierarchy? The structure of (32) can be expressed in finite state terms as follows (cf. Chomsky, 1957: 19):

37)



Chomsky (1957: 21) claims that it is *impossible* to produce all and only the grammatical sentences of the English language (a clear constructivist desideratum, see Lasnik, Uriagereka & Boeckx, 2005 for developments of Minimalism under constructivist desiderata). Thus, he arrives at the following conclusion:

38) *English is not a finite state language* (Chomsky, 1957: 21. Ex. 9)[10]

He provides examples of discontinuous dependencies like the following as evidence of his claim (1957: 22):

39) a. If S_1, then S_2
b. Either S_3 or S_4
c. The man who said that S_5, is arriving today

We have to disagree with (38), even under the light of examples like (39), including discontinuous dependencies (*if-then*; *either-or*; *the man-is*). All the discussion in Chomsky (1957) leading to (38) proves is that *some portions of the English language* (considered as a set of well-formed formulae, as was the use in the late ‘50s, particularly within transformational grammar) are not generable by a finite state grammar. Chomsky’s claim, clearly, is a plea for uniformity, which is, we think, a stipulation over the limitations of the automaton in which a formal procedure is implemented: if several grammars (parsing procedures) are available (from finite state grammars to mildly context-sensitive grammars, in the case of natural languages), why limit the generative-interpretative capacities to a single step in the hierarchy? An analogy with geometry (elaborated on from Author & Y, 2013) might help clarifying the scenario. Pylyshyn (2007: 156-158) proposes a series of problems that arise in a geometrical conceptualization of the mental space. These are:

1. *If we represent the fact that A is further from C than from B (AC > AB), then there would be a greater quantity of represented space (as distinct from a representation of more space, which makes no commitment about ‘‘amount of represented space’’) between A and C than between A and B. In other words, distance is represented in some form (perhaps in an analog form) so that each point in empty space is somehow explicitly represented.*

2. *If we represent A, B, and C as being ordered and collinear, then there would be an explicit representation of B as being between A and C (where by an ‘‘explicit representation’’ I mean that the relation ‘‘between’’ need not be inferred, but can be ‘‘read off’’ by some non inferential means such as by pattern matching).*

3. *If we represent three objects A, B, and C, then it would always be the case that the distance from A to B plus the distance from B to C would never be less than the distance from A to C (i.e., the triangle inequality of measure theory would hold so that AB + BC ≥ AC).*

4. *If we represent three objects A, B, and C so that AB is orthogonal to BC, then for short distances AB, BC, and CD it would be the case that $AC^2 + AB^2 = BC^2$ (i.e., distances would be locally Euclidean so that the Pythagorean theorem would hold for short distances).*

[10] Cf. Kornai (1985) for an inverse thesis: “*natural language stringsets are regular* [i.e., Finite-State]”. Unlike Chomsky, Kornai draws arguments from language data and acquisition, apart from considerations on theoretical simplicity. While his bases are wider, and more thoroughly argued for than Chomsky’s, the selection of data regarding nested dependencies is limited, and no evidence is provided regarding discontinuous dependencies (as in Wh-interrogatives or parasitic gaps).

These problems, fully valid within a Euclidean framework, dissolve as epiphenomenal if we consider that it is a different geometry that describes mental spaces. Our thesis, exposed in Author and Y (2013), is that *several geometrical models coexist in our minds and their frames are activated whenever necessary*. The performance of multitask computations is a known fact in human brain, controlling both conscious and unconscious bodily functions, and sometimes interchanging these functions. In the light of such a state of affairs, we will circumscribe ourselves to the best known geometrical models, each of which is understood as a model of apprehension of the phenomenological world, and 'activates' in a workspace W according to a scale of simplicity (from more complex to simpler):

40) Fractal >> Elliptical >> Hyperbolic >> Euclidean

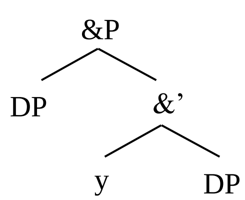
For the time being, we will assume this scale as being based on, among other things, 'intuitiveness' (on Aristotelian bases). In Euclidean geometry, the basis is the *point*, defined as that which has no dimension. Subsequent definitions of *line* (1 dimension) and *plane* (2 dimensions) build on the aforementioned definition of *point* which, following the Aristotelian way, is an axiom derived from simplicity and perceptual evidence. What we are saying is that to conceive a Euclidean space requires less use of working capacity because its basic tenets are the default case for our perception. This means that if a phenomenon can be conceptualized using Euclidean geometry, then there is no need to activate hyperbolic working spaces, as Euclidean geometry is simpler in the following crucial sense: their basic assumptions are derived, like all axioms in ancient science, from their simplicity and, mostly, evidence from a perceptual point of view. Moreover, recent research (Izard et al. 2010) has shown that Euclidean-modelable mathematical intuitions exist among people that have never been exposed to systematic education. If a Euclidean workspace is not enough, i.e., the interface effects we get from activating a hyperbolic W outnumber those we would get from a Euclidean W, then the hyperbolic frame is activated by interpretative interface requirement. The human mind can conceptualize what it has never perceived (like hypercubes), but, apparently, there is a limit determined by interface conditions. Our model of the mind, therefore, has more promising properties than that of Pylyshyn, due to the fact that we do not restrict its capacities *a priori*: multidimensional workspaces are a mathematical reality, and if the physical world is in itself a mathematical structure (e.g., Tegmark 2007), then our model has a great potential to arise as a plausible theory of the mind-brain as a physical system, its properties being determined by more general requirements of the structure of reality: for example, an operation applies to an object, and not to an operation. Taking a very basic concatenation operation as a primitive required by virtual conceptual necessity, the rest of the system is developed taking into account the specific properties of the relevant interpretative systems, physically and biologically constrained. We claim that the same operations apply when elaborating hypotheses about the grammar that generates a certain structure within the Chomsky Hierarchy, and the structure that is to be assigned to a certain fragment of language: in our view, Chosmky's claim (38), with consequences not only for grammar elaboration, but also for the hypotheses about the automaton in which the grammar is implemented, is to be modalized taking into account the variability of the computational properties of structural descriptions. In our terms, the interfaces' interpretative procedures range from finite state to mildly-context sensitive operations (i.e., the interfaces, particularly LF, are not computationally uniform, but parse syntactic objects selecting the simplest grammar that can generate the relevant object, while losing the least possible amount of information, particularly in structural terms). The human mind, in our proposal, is thus not a uniform PDA+ automaton, but a dynamic computational device that adapts actively to the nature of the input. Of course, Chomsky has a point when he claims that '*there are process of sentence formation that finite state grammars are intrinsically not equipped to handle*' (1957: 23), but this does not lead to the stronger claim that *no portion of English* (or any other natural language) *is finite-state*.

b) <u>Coordination</u>

Coordination structures have been forced into the X-bar template, in an attempt to make coordination an antisymmetric structure with the coordinator as a head (either overt or covert) and the terms of the coordination as Specifier and Complement, respectively. A uniformly X-bar theoretical approach to coordination, as the one defended in Progovac (1998, 1999), Zoerner (1995), Chomsky (2013)[11], among others. These authors argue that coordination structures are *uniformly* headed by a conjunction, and the Spec-Compl dynamics are homogeneous throughout the grammar. However, a uniform approach, to the best of our understanding, could not explain the following paradigm:

41) a. La subida **y** la bajada de la bolsa preocupan al Gobierno (Spanish)
*The rise **and** the fall of the stock Exchange worry*$_{[Pl]}$ *the government*.
b. La subida **y** bajada de la bolsa preocupa al Gobierno
*The rise **and** fall of the stock Exchange worry*$_{[Sg]}$ *the government.*

In the first case, arguably, both DPs [la subida] and [la bajada] motivate plural agreement in the V, being independent entities. Even if there is no hierarchical relation between the constituents (as a c-command relation would entail), it is possible (though not necessary, as we will see) that a &P analysis applies to the example, in the following manner:

42)


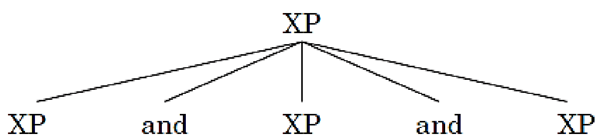
[11] Chomsky's approach, however, differs in a number of details: while adopting an X-bar template, he also assumes a transformational operation applying to a base form (following Moro's 2000 dynamic antisymmetry), such that (2013: 46):

i) [Conj [X, Z]]
ii) [X [Conj [~~X~~, Z]]]

Notice, however, that (ii) equals (42), even though (42) has been base-generated, and is thus *derivationally* more economical.

However, if coordination structures are *all* XPs (&P, PredP, etc.), it is hard to see how to account for the agreement paradigm in (41), among other empirical phenomena (basically, lack of scopal relations between coordinated terms in some constructions; while binding effects can appear in others, see Progovac, 1998: 4 for some binding-related effects). Our proposal for coordinated structures goes quite along the lines of Jackendoff (1977), basically, the representation in (43):

43)



However, there is no reason for the whole constituent to be labeled identically to the categorial label of one (or all) of its constituents: if the functional potential of the whole constituent is that of a nominal construction, the label will be, say, N; if all coordinated elements (regardless their category) indicate *manner*, that will be the label. (e.g., [*manner* [[PP] and [Adv]]]; as in 'They ate quickly and in an anxious way'). All in all, the *notation* we use for the label is not significative (i.e., *event* instead of VP; *cause* instead of *v*P), as long as there is an explanation of the semantic contribution of each node.

Quite the same happens when we are dealing with clauses instead of DPs. In our terms, the coordinator is a 'pivot' between two clauses, each a separate derivational cascade (i.e., independently derived monotonic objects), forming a non-monotonic object. Otherwise, extraction should be possible:

44) *Who$_i$ did Mary greeted John and t_i?

Ross (1967: 89) made this situation explicit, via the so-called Coordinate Structure Constraint (CSC):

> *In a coordinate structure, no conjunct may be moved, nor may any element contained in a conjunct be moved out of that conjunct.*

Some examples in English are the following (taken from http://www-personal.umich.edu/~jlawler/aue/ross.html):

45) a. Bill cooked supper. What did Bill cook?

b. Bill washed the dishes. What did Bill wash?

c. Bill cooked [supper]$_i$ and washed [the dishes]$_j$.

d. *What$_i$ did Bill cook t_i and wash [the dishes]$_j$?

e. *What$_j$ did Bill cook [supper] and wash t_j?

Extraction constraints would follow straightforwardly if a monotonic vs. non-monotonic Merge approach to structure generation was adopted. If each structure is generated in separate workspaces, and unified in a third workspace, then constraints for extracting material out of non-monotonic units can be subsumed to their derivational history. Graphically,

46) [[Bill cooked supper] and [~~Bill~~ washed the dishes]] W_3

↑

and

[Bill cooked supper] → ← [Bill washed the dishes]

W_1 W_2

In the same way we have derived constraints on displacement (focusing on A/A’ asymmetries) on X & Author (forthcoming), the alternance between monotonically and non-monotonically derived syntactic objects can simplify the system of constraints over extractions. Basically, and simplifying the scenario (although not much), *extraction is possible only within the limits of a monotonically derived object* (see Author, 2013 for an analysis of parasitic gaps, involving non-monotonic units, appealing to type-token dynamics). This means that dependencies within monotonic cycles can be established by means of finite state grammars, if Uriagereka’s (2012: 53) claim that ‘*an exhaustively binary phrase-marker, none of whose branches symmetrically bifurcates, can be expressed in FS* [Finite State] *fashion*’.

An important caveat at this point is that, if the headed representation in (42) was along the right lines for all instances of coordination, then extraction from the second term of the coordination should be possible (since complements are derived in the same derivational cascade as heads, thus configuring a single monotonic object), a prediction that is at odds with the data presented in (45 e), where the whole VP [wash ~~what~~] is derived, in a bottom-up fashion, monotonically in the same derivational cascade in which the head [and] is introduced (following the model in Uriagereka, 2002a). However, a finite-state compatible derivation along the lines of (46), in which all terms of a coordination are independently (and monotonically) generated in separate workspaces, then unified via non-monotonic Merge, predicts CSC effects by appealing to the computational properties of the resulting phrase marker without additional stipulations. Needless to say, much empirical research is pending, but this seems a promising line of inquiry.

It is to be noticed that, so far, every syntactic object (of arbitrary complexity) we have claimed to enter a labeling process is ultimately binary: this scenario emerges as the simplest non-trivial option[12] we can think of:

47) Binarity requirement for Labeling:

For any non-terminal syntactic object K = {α, β…n}, a label L is determined at the semantic interface for a pair (α, β) ⊂ K when Analyze applies, after each derivational step.

Let us clarify the scenario we have in mind. We adopt a version of the 3-dimensional, Calder-mobile-like syntactic structure proposed primarily by Uriagereka (1998: 276-277), Lasnik, Uriagereka & Boeckx (2005: 35), and radicalized in Author (2012b) to *n*-dimensionality and *n*-ary branching. *n*-dimensionality, that is, the localization of structures in conceptual spaces defined by *n* coordinates, is compatible with semantic conditions insofar as conceptual structure can be mapped in *n*-dimensional vector spaces (see Graben et. al., 2008 for discussion and some references): a phrase marker, if defined in terms of the location of its terminals in the conceptual space, must extend in more than 2 dimensions (we will come back to this below). However, PF being essentially Markovian (see Idsardi & Raimy, in press; Author, 2013b for a *dynamical frustration* approach to the semantics-phonology tension), Spell-Out takes a 'snapshot' of the *n*-ary structure S at a derivational moment T, more specifically, when there is a set F of phonological matrices to (sub-)optimally materialize Sem ⊂ S and there is no F' such that F' can materialize more of those features (in a word, when there is a distributionally specified phonological matrix corresponding to a set of syntactic nodes, in very much a Distributed Morphology way), performing a forced 'Markovization' (or dimensional 'flattening') of the symbolic structure. Relations of linear precedence[13] are mapped from that snapshot, without any command requirement, revisiting the 'snapshot' proposal made by Lasnik, Uriagereka & Boeckx (2005: 115) loosening the binary-branching requirements, and eliminating the LCA. Of course, since the structure is like a Calder mobile (but with *n* branches instead of two, cf. Uriagereka, 1998: 276-277; Lasnik, Uriagereka & Boeckx, 2005: 115, ff.), some of those snapshots will be ruled out by the interfaces, more specifically, via a process of neurological reorganization (e.g., Cherniak, 2009; Amari, 2003), possibly with statistical bases: if a snapshot is ruled out *n* times (a threshold to be determined empirically), it is just not taken anymore. Labeling, understood as 'label recognition'(despite notation), works in a similar way, applying to pairs of objects when the elements involved do *not* convey the same kind of information (see discussion above).

An essential feature of the binarity requirement in (47) is that it does not make any claim with respect to the inner complexity of the objects (a, b, …*n*): α can be a Markovian object constructed via *n*-ary Merge, and β can be a terminal, or a command unit itself. Thus, we avoid the

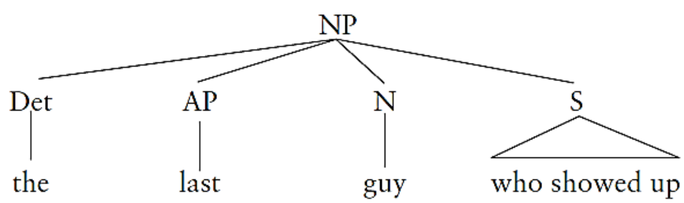
[12] We will not discuss here the proposals of Unary Merge (Adger, 2011) and Merge involving a null terminal (e.g., De Belder & van Craenenbroeck, 2011), insofar as, for interface purposes, both {{α}} and {α, Ø} are equal to α at the semantic interface. See Author (2011) for discussion.

[13] Here we take precedence to be the relation by default, although it does not have to be so: Uriagereka (2012) proposes (as a logical alternative) a Mirror LCA, which maps c-command relations to phonological 'posteriority' relations. We will not deal with this issue here.

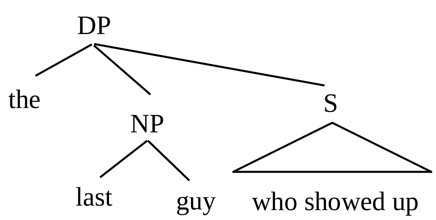
complications of limiting the scope of our labeling operation to H-α or XP-YP relations (cf. 5), but maintain the advantages of binary labeling. This model requires, of course, the additional assumption that the mind is not computationally uniform: a syntactic object can contain *both* linear and discontinuous dependencies, such that a fixed parser might assign either too much or too little a structure to a certain object. The former situation is common in orthodox accounts of adjective iteration and coordination, consider Cinque's (1999) FP for adjectives, and Progovac's (1998, 1999) &P for coordination (both assigning a rich –functional- structure to Markovian dependencies). The latter, admittedly less common, can be found in some flat structures proposed in Culicover & Jackendoff (2005), as well as Hale's (1983) analysis of Walpiri as a non-configurational language. Culicover & Jackendoff's analysis of nominal structures (2005: 140), for instance, fail to formalize the semantic relation between D and N, in which the D limits the denotation of N, thus making it referential (see Author, 2012; Escandell & Leonetti, 2000). Let us confront both structures for a sentence like (48):

48) The last guy who showed up

49) a.



b.



The differences between both structures are clear: (49 b) encodes the asymmetric relation between semantic substance (NP) and the constituents that restrict the reference of that semantic substance, a semantic relation that requires (under standard logical assumptions) a relation of scope between those elements, such that the constituents limiting the reference of the NP (the D and the relative clause) are also dominating categories hierarchically speaking. This representation is also better equipped to account for semantic-pragmatic effects like those formalized in Relevance Theory (Escandell & Leonetti, 2000). In this proposal, functional categories D, T, and C (*v* was not included in their first account) convey instructions as to how to interpret the relation between conceptual content under their scope, thus being *procedural categories* (2000: 368). A model of mixed phrase markers, including phrase-structural *and* Markovian dependencies has not only empirical (as we saw in coordination and iteration), but also theoretical advantages, insofar as interdisciplinary work and collaboration between linguistic (syntactic, semantics, pragmatic) and computational theories.

3.4 Some further consequences and extensions: towards a dimensional theory of predication

The *n*-ary branching phrase structure model we have sketched in previous sections has far-reaching consequences for a theory of predication relations, particularly when we are dealing with phrasal predication (in traditional terms, an XP modifying another XP, or, crucially, more than one). So far, we have worked out the following assumptions:

50) a. Merge manipulates *n* objects at once
b. Label applies to *two* objects, each of arbitrary complexity
c. Labels are *recognized* at the semantic interface (not *created* by some syntactic algorithm)
d. Phrase structure dependencies are *not uniform*

In this section we will sketch a theory of predication based on an extension of the formal system entailed by premises (50 a-d). However, it is to be noticed that the extension is not a necessary entailment of those premises, and a consistent system is also attainable if the extension is negated. Let us make this extension explicit:

51) a. Symbolic objects are defined in the topological mental space in terms of coordinates
b. There is no *a priori* limit to the number of coordinates (i.e., axes) an element is to be defined by

How would this work, under the labeling assumptions we have been sketching so far? Assume a Cartesian system of two axes[14], so that we can define some basic relations taking *n* syntactic objects:

52) a. Sisterhood: different value for *x*, same value for *y*
b. Immediate containment: same value for *x*, different value for *y*

Of those relations, only (52 a) is of some interest, as (52 b) is dependent on X-bar theoretical assumptions on projection (i.e., every head projects *both* X' and XP, even if there are no Spec- or Compl- in the phrase). Interestingly, the Markovian dependencies we have discussed can be defined taking into account (52 a), *y* being constant: if the syntax of adjuncts, coordination, and iteration (that we have dealt with here) is essentially Markovian (see Uriagereka, 2005; Uriagereka & Pietroski, 2002 for more discussion), for example, we need a formal system to account for semantic effects (e.g., lack of scope relations between them). A geometrically-based system is, in our opinion, just as good as any other, empirically speaking (and perhaps theoretically simpler), thus worth pursuing.

The central point of this section is to define predication relations and projection (i.e., labeling) within this system we have sketched here (and in Author, 2012b). Departing from a Euclidean framework, we assume that the first element in a derivation is defined as a point, with a single coordinate. The second element is defined in relational terms with the first, and thus we need a further coordinate. Then, as the derivation unfolds, a Calder mobile-like element is assembled, in 3-

[14] Uriagereka (2002b) proposes two axes as well, but corresponding to paradigmatic and syntagmatic relations. We will not consider those notions, our axes are formal tools to describe a topological mental space used for linguistic derivations as well as any other computational process.

D within a mental workspace. Notice that, even if there were reasons to claim that the first element to enter a derivation is defined by more or less coordinates than we have argued here, the derivational dynamics would not change. This leads us to the central claim of this section, which is (provisionally) (53):

53) If a predicate is to have scope over a referential (either sortal or eventive) variable, the number of the predicate's coordinates in the mental working area properly contain the number of the arguments' coordinates[15].

For instance, let us see what a predication relation over a sortal entity would look like:

54) a) N = (x, y)
b) A (if A is a predicate and takes N as an argument) = (x, y, z)

And so on. This allows us to define very precisely the scope of multiple modifiers, as in iteration (e.g., if n As modify an N, but neither has scope over one another, then they are all defined by the same n-plet of coordinates in the cognitive workspace). At this point in the development of the proposal, it is not really crucial whether N is a pair, a triplet, or a single coordinate, just that if N = (n), the predicate that takes N as its argument will be defined as (n+1). In other words, *for n dimensions*[16] *of α, f(α) = n+1* (Cf. Uriagereka, 2002b: 296). Interestingly, this proposal goes along with the distinction between monotonic and non-monotonic merge, insofar as monotonic Merge builds structure while maintaining the number of relevant dimensions; non-monotonic Merge, 'bringing' objects from different workspaces, introduces further dimensions in the construal (without the formal necessity of 'bending' space onto itself).

The proposal we have just introduced has far reaching consequences for the analysis of problematic data involving discontinuous dependencies that, to the best of our knowledge, cannot be modeled with a standard PS grammar (unless further assumptions, like node multidominance, are introduced, but those, as Chomsky, 2013: 40, fn. 20 says, '*The concepts of multidominance, "late Merge", and some others postulate an extension of Merge*', thus not being part of standard PS grammars and probably drifting away from Chomsky's concept of 'the simplest scenario'). In (45 c), for instance, there is no need to assume subject ellipsis if we consider that, since [Bill] is the subject of two VPs, the latter are defined in n-axes (say, 2, since we have an argument and its selecting V) and the former, in n+1 axes, thus modifying both VPs without the need to include a further copy / token of the subject DP in the representation plus a deletion rule. Notice that the proposal could work in typologically different languages, and different constructions as well, consider (55):

55) Iuturnam misero sucurrere fratri / suasi et pro vita maiora audere probavi (Verg. *Aen*. XII, 813-814)

[15] The arguments in this section are related to, even though not the same as, those raised by Uriagereka & Pietroski (2002) regarding the dimensionality of the thematic system (i.e., modification taking place within VP). However, we will neither use the same, Neo-Davidsonian, notation, nor focus on Aktionsart-related conditions on sub-event modification, which is a central point in Uriagereka & Pietroski's paper.
[16] We assume here that each axis corresponds to a dimension.

Iuturna$_{ACC}$ unfortunate$_{DAT}$ rescue$_{INF}$ brother$_{DAT}$ / persuaded$_{1SgPerf}$ and for life better dare$_{INF}$ esteemed$_{1SgPerf}$

The accusative argument [Iuturnam] is the subject of two ECM clauses depending on the finite Vs [probavi] and [suasi], coordinated by [et]:

a) [ego probavi] Iuturnam$_{ACC}$ sucurrere$_{INF}$ misero fratri
b) [ego suasi] Iuturnam$_{ACC}$ audere$_{INF}$ pro vita maiora

The derivation would proceed along the same lines of (46), with [Iuturnam] defined within the mental workspace by an *n*-plet of coordinates properly containing the *n*-plet defining the VPs, derived monotonically in separate workspaces. Notice that examples like (45 c) and (55) force us to refine the principle in (53): in this case, an argument is forcing the inclusion of a further dimension (i.e., a further axis) insofar as it is an argument of two separate VPs, derived separately and coordinated (recall the discussion about coordination as an essentially Markovian relation between symbolic objects). It seems that the relevant condition has to do with the establishment of dependencies in general, despite the argument / predicate distinction. While (53) might do the job for single-workspace operations, when the picture gets more complicated, a more complete theory of dependencies is to be invoked, theory that is currently under research within a dynamic model of the mind, allowing mixed dependencies within a single symbolic object.

So far, we have dealt with ‘argumental’ dependencies, involving subjects. Let us see a more extreme case, what would happen with an ‘adjunct’ element, in this case, an absolute ablative. Consider the following Latin example:

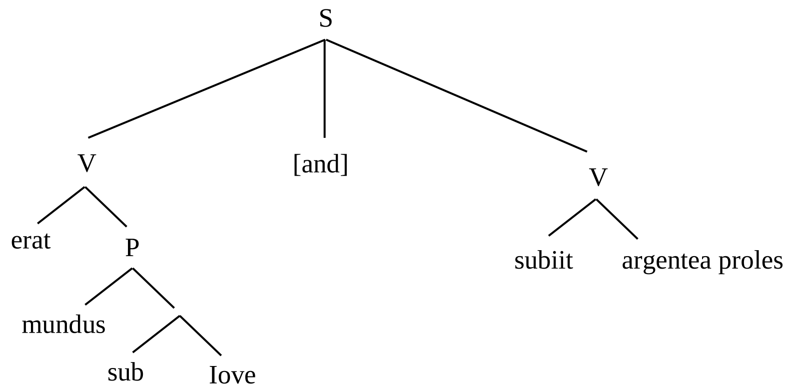
56) Postquam Saturno tenebrosa in Tartara miso / sub Iove mundus erat, subiit argentea proles (Ov. *Met*. I, 113-114)
After Saturn$_{ABL}$ dark to Tartarus sent$_{PartPastPassABL}$ / under Jupiter world was, rose silver offspring

In (56) we have a single absolute ablative [Saturno tenebrosa in Tartara miso] modifying two finite clauses, each with its own nominative subject, [sub Iove mundus erat] and [subiit argentea proles]. In turn, both propositions are coordinated via asyndeton, there being no hierarchical relation between them: the temporal reference of each perfective V [erat] and [subiit] is understood in relation to the absolute ablative (i.e., the world was under Jupiter’s command *and* the silver offspring rose both after Saturn was sent to the dark Tartarus), and not in relation to each other. In our opinion, there are two ways to go round this situation:

a) Assume there is an elided copy of the absolute ablative within the domain of one of the VPs
b) Assume the *same* structural token of the absolute ablative actually modifies both VPs

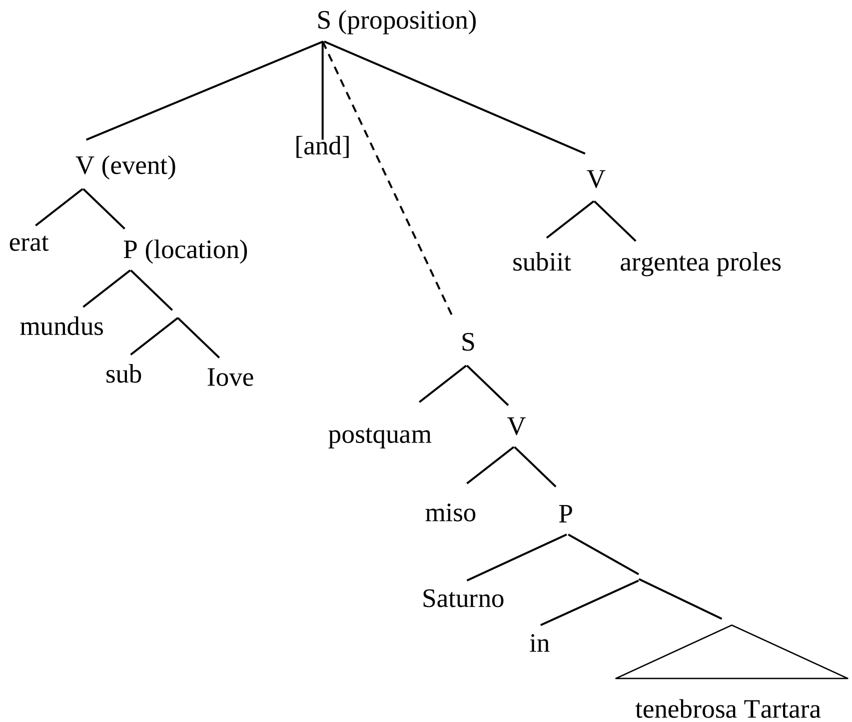
To the best of our knowledge, there is no literature expanding on (a) for cases like these (involving an element whose specific location within the periphery of the clause is uncertain, unless assuming an extremely rich functional skeleton, in detriment of representational economy), particularly for a ‘non-configurational’ language like Latin. Let us develop option (b) within the framework sketched above: VPs (without considering the external argument, which can be non-monotonically merged an thus would complicate the point we are trying to make here) are monotonic objects, each derived in a separate workspace. We present the coordinated structure as (57):

57)



In (57), arguably, we have only dealt with two axes for each VP, since they have been monotonically assembled (notice that both verbs are unaccusative, therefore, subjects originate as V complements, in traditional terms). The need for a null version of [and] instead of asyndetic coordination is not clear, it is possible that mere non-monotonic Merge of both command units can do the job just as well. However, in this particular case, the element that we have to account for is the absolute ablative, which has scope over *both* VPs. In this case, should we accept the premises in (53) with the caveat made above, the absolute ablative is to be defined in a workspace by a set of coordinates including (say) 3 axes: in that way, it can have simultaneous scope over both VPs without affecting the label of the whole object, which remains S(entence) or any other symbol we can use to model a proposition (including symbols drawn from Montague grammar, for instance, or just a formal representation of the proposition dominated by the node, as in HPSG or other unification-based models, see Shieber, 1986 for discussion). A graphic representation would go along the lines of (58), with the dotted line denoting the added axis (see Hale & Keyser, 2002; Mateu Fontanals, 2002 for a discussion about the lexical-conceptual structure of unaccusatives):

58)



We have to take into account that each monotonic cascade is in turn expressible in finite-state terms, therefore linearizable independently (in accordance with Uriagereka's 2002a version of Multiple Spell-Out). In this framework, a unit is Spelled-Out as soon as it can, therefore eliminating the necessity to wait until a phase head is merged as in Chomsky's (2000, 2004) model. The multiple dimensions we have used here are 'flattened' when Spelled-Out, in order to convert a type-0 object into a type-3 object. The direct consequence this proposal has for the architecture of the mind and its computational properties is that the syntax-phonology interface is by no means 'transparent', as it involves dynamic Markovization of *n*-dimensional structure. On the other hand, the semantic component, as pointed out above, is compatible with more complex forms of computation, perhaps exceeding Turing-computability, as Uriagereka (2012: 7) suggests (for instance, quantum computation, as we pointed out in Author, 2013a, b). As we see once again, the assumptions we make about structure building operations have far-reaching consequences for the computational properties we assign the mind in charge of performing those operations.

4. Conclusions:

In this paper we have analyzed a range of proposals concerning structure building and structure mapping operations, and the way the resulting symbolic objects are recognized for the purposes of further computations, what is usually referred to as 'labeling'. We have seen that orthodox generative grammar limited the power of the generative algorithm to two objects, while empowering transformational operations: as a consequence, if natural language is claimed to have a context-free grammar, implemented in a Turing-machine-like automaton (e.g., Watumull et. al., 2014), the power of the context-free grammar is limited from including linear, Markovian dependencies, to strictly 2-D, binarily-Merged (and thus binarily-labeled) symbolic structures. That is, as Lasnik & Uriagereka problematize, it is possible that the generative engine assumed in the Minimalist Program sets both upper and lower boundaries to its own generative power based on intra-theoretical stipulations on labeling and phrase structure (a problem already present in Chomsky & Miller, 1963, as we noticed above): surprisingly, the same problem is found in arguments in favor of *uniform* regular models for phrase structure implemented via finite-state grammars (see Kornai, 1985 for an example of the latter perspective; and Baltin, 2003 for discussion on whether considerations of 'optimal design' would not favor Markovian models, which are limited to the present state –thus blocking by principle both *look ahead* and *backtracking*- instead of Turing models). We reviewed non-orthodox approaches, in which *n*-ary concatenation is assumed, and argued in favor of a version of *n*-ary Merge in *n*-D mental workspaces, a theory which, we think, adequately captures the semantic properties of problematic structures, including (but not limited to) iteration and coordination. What is more, our proposal *allows* binary Merge as an option (monotonic Merge), thus maintaining the descriptive and explanatory adequacy of the strong points within the chomskyan Minimalist Program and other forms of phrase structure grammar, while increasing the possibilities of inter-theoretical work by revisiting the generative engine and loosening (or, directly, eliminating) some stipulations constraining its application. With respect to its implementation on an automaton, we claim that the mental grammar, being dynamic (allowing mixed dependencies within symbolic objects), can go 'back and forth' within the Chomsky Hierarchy (for a strict, non-dynamic formalization of grammar types, see Chomsky, 1959: 142-143), selecting at each derivational point the simplest grammar that allows it to parse a given symbolic structure. This led us to propose a model of the mind in which the object is *not* computationally *uniform*, but able to switch grammars, and actively parse (linguistic and non-linguistic) objects while adapting to their complexity. If labels mark how a syntactic object is to be interpreted in subsequent derivational steps, the algorithm we select for labeling is crucial in parsing, and so we have tried to extend the dynamic character of structure building to structure labeling. Needless to say, much empirical work is pending, as well as thorough theoretical investigation about the characteristics of mixed models of the mind. Hopefully this article will contribute (together with some of those we have reviewed here) to generate awareness of the computational consequences of the structure building / mapping algorithms assumed in a particular framework as well as the physical / neurological substratum that licenses the aforementioned computational properties assigned to a certain formal automaton.

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