

## On the computational modeling of English relative clauses

**Abstract:** Even in this era of parameter-heavy statistical modeling requiring large training datasets, we believe explicit symbolic models of grammar have much to offer, especially when it comes to modeling complex syntactic phenomena using a minimal number of parameters. It is the goal of explanatory symbolic models to make explicit a minimal set of features that license phrase structure, and thus they should be of interest to engineers seeking parameter-efficient language models. Relative clauses have been much studied and have a long history in linguistics. We contribute a feature-driven account of the formation of a variety of basic English relative clauses in the Minimalist Program framework of Chomsky (1995, 2001), that is precisely defined, descriptively adequate, and computationally feasible in the sense that we have not observed an exponential scaling with the number of heads in the Lexical Array (LA). Following proposals by Gallego (2006) and Pesetsky & Torrego (2001), we assume an analysis involving a *uT* feature and *uRel* feature, possibly simultaneously valued. In this paper, we show a detailed mechanical implementation of this analysis, and describe the structures computed for *that*, *which*, and *who/whom* relatives for standard English.

Keywords: English relative clauses, Minimalist Program, computational modeling

## 1 Introduction

Relative clauses have been the subject of much research in modern Generative Grammar.<sup>1</sup> These constructions are of particular interest because the head noun of the relative clause appears to be doubly licensed. In (1)a, resp. (1)b, the relative clause head noun *man* appears to obtain both grammatical case and a theta-role in two distinct positions (assuming that there is only one head noun *man*); i.e. as object (resp. subject) of the relative clause verb *saw* (resp. *loves*), and as object of the matrix verb *like*.

- (1) (a) I don't like [the man who John saw ~~man~~].  
(b) I don't like [the man who ~~man~~ loves Mary].

---

<sup>1</sup> See Brame (1968), Schachter (1973), Carlson (1977), Chomsky (1977), Vergnaud (1974), Kayne (1994), Borsley (1997), Bianchi (1999, 2000), Citko (2001), Chomsky (1995), Gallego (2006), de Vries (2002), Schachter (1973), Salzmann (2017), Radford (2016), Radford (2019), *inter alia*.

Analyses of relative clauses in the Generative Grammar tradition have attempted to explain the structure of relative clauses, and clarify how a relative N is licensed. Analyses can be loosely categorized into *matching* analyses, in which there are two separate relative nouns that have the same reference, and *head promotion/raising* analyses in which there is only one relative noun that undergoes movement. In an operator movement analysis, like that in (2)a (Chomsky 1977, Chomsky & Lasnik 1995), a relative operator is base generated in the relative clause and raises to the specifier of the CP. It then gets its interpretation by being associated with an external noun, expressed through coindexation here. In another account, shown in (2)b, there are two separate relative nouns that have the same reference, and the lower noun is deleted under identity (cf. Citko 2001). Both of these types of analyses in (2)a-b have been referred to as matching analyses, as there are two separate relative nouns. In a head promotion/raising account, the nominal head of a relative clause undergoes movement outside of the clause, as in (2)c (Brame 1968, Schachter 1973, Vergnaud 1974, Kayne 1994, Borsley 1997, Bianchi 2000, etc.). Unlike a matching analysis, there is only one relative noun which undergoes movement, and it is basically licensed in two positions.

- (2) a) I don't like the man<sub>1</sub> [who/OP<sub>1</sub> C John saw ~~who/Op~~<sub>1</sub>]  
 b) I don't like the man<sub>2</sub> [[who/OP ~~man~~<sub>2</sub>]<sub>1</sub> John saw [who/Op ~~man~~<sub>2</sub>]<sub>1</sub>]  
 c) I don't like the [man<sub>2</sub> [[who/D ~~man~~<sub>2</sub>]<sub>1</sub> John saw [who/D ~~man~~<sub>2</sub>]<sub>1</sub>]]

The matching analysis does not face the problem of a single noun receiving case and a theta-role in two positions, as it makes use of separate but co-indexed nouns. On the other hand, a raising analysis does not require a separate matching/coindexation operation. A thorough comparison of the various approaches, and their variants, is beyond the scope of this paper,<sup>2</sup> but we adopt a version of the raising/promotion account in which new NPs with the same core noun lexeme can be formed through Internal Merge, obviating the need for a separate matching operation. At the same time, we avoid the problem of a single noun receiving multiple theta-role and case assignments, through the use of separate D heads.

English relative clauses pose a non-trivial problem as they vary with respect to the content of the head and edge of the CP, as summarized in Table 1. None of the standard English relative

---

<sup>2</sup> See Aoun and Li (2003), Radford (2016), and Salzmann (2017), among others for comparisons of the head raising and matching analyses, as well as arguments for and against each approach. Salzmann favors a matching analysis, whereas Radford and Aoun and Li argue that both approaches are utilized (depending on the type of relative clause).

clauses permit *which/who that*<sup>3</sup>; there being a well-known ban on doubly filled COMP (cf. Chomsky & Lasnik 1977, among others). Object relatives permit an empty COMP (indicated by  $\emptyset$ ), but subject relative clauses do not.

	Type of relative	Restrictions	Examples
a)	Object relative	which/that/ $\emptyset$ *which that who(m)/ $\emptyset$ *who that	(i) the book which/that/ $\emptyset$ I read (ii) *the book which that I read (iii) the man who/ $\emptyset$ John saw (iv) *the man who that John saw
b)	Subject relative	who that *who that * $\emptyset$	(i) the man who loves Mary (ii) the boy that called Mary (iii) *the boy who that loves Mary (iv) *the boy $\emptyset$ called Mary
c)	Object headless relative	what *what that	(i) what I read (ii) *what that I read
d)	Subject headless relative	what *what that	(i) what annoys John (ii) *what that annoys John

Table 1: Examples of core relative clauses<sup>4</sup>

This paper presents a computational model of relative clauses based on linguistic proposals in the Minimalist Program (MP) framework.<sup>5</sup> We have a full computer implementation of the theory, verified across all core examples presented in this paper.<sup>6</sup> The detailed step-by-step derivations computed by the program are too lengthy for inclusion in the body of this paper; they may be found in the online Appendix, thus permitting the reader to verify the accuracy of our claims.<sup>7</sup> These derivations should also prove helpful to both linguists and engineers who wish to understand how the components of the theory interact in full detail. To our knowledge, this is the first computer implementation in the MP framework

<sup>3</sup> The use of *who* vs. *which* is dependent on whether or not the head noun is human/animate and is subject to minor stylistic variation. In particular, *who* appears to require a human head noun (although it is sometimes used for animals with names; e.g., see <https://erinwrightwriting.com/refer-animals>), whereas *which* can be non-human and animate, but it can also be inanimate.

<sup>4</sup> Most of these examples are from Gallego (2006), who has taken some of these examples from other works such as Kayne (1994) and Bianchi (1999).

<sup>5</sup> Implemented in Prolog and in Python independently, nearly identical results were obtained, thus providing verification of correct implementation, as well as verification for the consistency of the theory. This involves checking for intended derivations, for the absence of unintended derivations, as well as crashes in cases of ungrammatical input.

<sup>6</sup> Our model makes logical consistency checks with respect to feature valuation. The model also implements disjunctive logic, i.e. multiple derivations are, in principle, possible. Any logical inconsistencies will result in non-convergence for a particular derivation, but other derivations may proceed independently. However, we also use the notion of economy of feature-checking to compare and dis-prefer other successful derivations.

<sup>7</sup> Complete derivations, implemented independently by each author, are available at [redacted for anonymity].

to accurately generate the complete set of basic subject and object English relative clause constructions, while also accounting for the usage of *which*, *that*, and *who(m)* in relative clauses.

## 1.1 Computational modeling of linguistic theory

The computational implementation of linguistic theory requires overcoming substantial barriers including: (1) the careful selection of compatible sub-theories of grammar, a particularly important aspect as relative clauses involve both theories of the noun phrase (NP) and sentential structure (CP); and (2) theory mechanization, as linguistic theories are not specified with a mechanical architecture in mind. We take a *linguistically-faithful* automatic computer program to be one that autonomously assembles syntactic derivations (beginning with a list of primitive lexical items). The Minimalist Program (MP) continues a long line of inquiry into the nature of the language faculty; this being a theory of competence, and our implementation concretely realizes the generative procedure. The problems of externalization, e.g. the mapping of linguistic representation into instructions to the sensory-motor system, and the problem of (efficient) parsing are important ones for which scientifically-motivated answers are still limited. In this paper, we limit our attention to the modeling of the generative procedure. We emphasize that the generative procedure does not automatically imply a psychologically-realistic parser; it generates structures and sentences starting from a list of (user-supplied) lexical heads.<sup>8</sup>

Let us consider the general problem of concrete modeling. First, the theory should be precise and substantial enough to withstand scrutiny. It must be possible to algorithmically specify details down to the level of the linguistic primitives assumed in the MP framework, i.e. Merge (combing syntactic objects (SOs)) and probe-goal feature checking (agreement relations between features on two SOs). This is a non-trivial requirement as theoretical development in the MP framework proceeds apace and in radical fashion.<sup>9</sup> Suppose we are able to select a sufficiently precise and broad theory. We also need to provide a computationally-tractable

---

<sup>8</sup> Simply by selecting a correct list of lexical items, our model implies a semi-decidable parsing procedure in the sense that we can explore a finite number of possible options, e.g. with respect to movement and possible empty categories. The problem of convergence for ungrammatical input leaves us with only semi-decidability. An efficient parser would require additional constraints to effectively limit the search space. A cognitively plausible model would also have to account for psycholinguistic data, i.e. express ranked preferences. We note attempts to account for this, e.g. the surprisal theory of Hale (2001), have been made, but not within the MP framework. We leave this important topic for future work.

<sup>9</sup> For instance, a simple glance at the theoretical apparatus and structural descriptions suffices to confirm that the MP framework described in Chomsky (1995) differs substantially from Chomsky (2001), which, in turn, differs substantially from Chomsky (2013).

implementation. For example, the implementation should not exhibit combinatorial characteristics, such as in terms of temporary syntactic ambiguity or lexical ambiguity, that require exponentially-scaled resources, e.g. as the list of initial heads grows. Finally, in line with broader MP goals, we submit that an implementation of a particular phenomenon should be succinct in terms of the number of construction-specific theoretical devices required, ideally none. Every grammatical feature or data structure we specifically introduce to limit or control derivations is an additional burden, not only to acquisition and evolution, but also with respect to the goal of simplifying core syntax. As we will show, our system is *parameter-efficient* in this sense. Since relative clauses embed sentential structure, any model of relativization must also include substantial modeling of sentential structure, and therefore will be of broad relevance to general modeling of grammar.

We need to also motivate the MP framework itself. For theoretical linguistics, this requires little justification: the goal of a universal theory built around binary Merge has resulted in a large body of work (since Government-Binding theories of the late seventies) that has contributed greatly to the understanding of language. However, there remains a substantial gap from theoretical to computer models. Müller (2015, 35) writes that there are no “large-scale computer implementations that incorporate insights from Mainstream Generative Grammar.” We believe we have substantially narrowed that gap by clearly demonstrating that theoretical achievements can be implemented. Furthermore, Müller (2015, 37) writes that the system presented in Fong and Ginsburg (2012), which is similar to the system presented in this paper, “neither parses nor generates a single sentence from any natural language.” We wish to clarify that we compute linguistic derivations which are spelled out as phrases and sentences of English.

We do not employ a phrase structure grammar-based formalism in this paper, choosing instead to implement devices described by theory directly. We are aware that there is a substantial body of work centered around the Minimalist Grammar formalism, e.g. Stabler (1997, 2011), including computational implementations such as Hale (2003), Harkema (2001), and Torr, [Stanojević](#), Steedman & Cohen (2019), and Indurkya (2021). Detailed comparison of our work with an equivalent Minimalist Grammar is a topic that is beyond the scope of this paper.<sup>10</sup> There are also proposals for relative clauses in other linguistic frameworks such as

---

<sup>10</sup> Minimalist Grammar (MG) is a grammar formalism that embraces strict feature checking to drive displacement (movement), i.e. Internal Merge, and selection (External Merge). Lexical entries embed a sequence of (possible arbitrary) formal features to be applied in sequence to fix the correct word and hierarchical order (at the cost of requiring multiple lexical entries to account for different derivation paths). We limit the discussion here to the

Head-Driven Phrase Structure Grammar (HPSG), e.g. Sag (1997), that lend themselves to computational implementation, e.g. Müller (2015). Sag (1997) takes a construction-specific approach to relative clauses, slicing them up into a sort hierarchy.<sup>11</sup> In Chomsky’s MP, construction-specific rules are frowned upon: the goal being to reduce constructions to universal primitives. We also include key examples from Sag (1997) and show how they are handled in the MP framework.<sup>12</sup>

## 1.2 The Minimalist Program

It is important to note that the Minimalist Program is a program of research inviting many different theories under the umbrella of eliminating complex operations in favor of the simplest possible operations that can be conceived (thereby contributing to evolutionary plausibility). Our model follows much of the theory outlined in Chomsky (2000, 2001, 2008). We review the core assumptions and mechanisms below.

At the heart of the theory is binary set-Merge, the simplest possible operation taking two objects that, when iterated, creates hierarchical structure. Merge can result in either symmetric structure, resulting from set-Merge, or in asymmetric structure, resulting from pair-Merge (Chomsky 2000, Chomsky 2004). Pair-Merge is asymmetric in that one of the two merged objects in Pair-Merge is rendered inaccessible to further operations (not so in set-Merge). Set-Merge can be internal or external. Internal Merge (IM) encodes displacement from within a SO, and External Merge (EM) combines two distinct SOs, encoding argument structure. As a concrete example, EM applies to an object DP and a transitive verbal root V forming the set {V, DP}, followed by EM twice to form the theta configuration {DP, {v\*, {V, DP}}}. v\* is a verbalizer that licenses the outer DP subject. For unergatives, e.g. *sleep*, the equivalent configuration is {DP, {v, V}}, and v is the corresponding verbalizer.

---

major points of departure from MG, including that displacement is not always feature-driven, the null hypothesis being that it is free (to take place or not). It is generally accepted that Merge is concerned only with hierarchy, i.e. encodes nothing about word order, e.g. Chomsky (2013). A MG account adds formal features and Merge-operations to encode the correct word order. Each additional formal feature requires extraordinary justification due to evolutionary and acquisition burdens, criteria relevant to the notion of *Genuine Explanation* (Chomsky 2021). We finally note that theoretical linguistics has not adopted MG, and MG has not tracked the trajectory of recent theory, e.g. Labeling theory, and the fact that Internal Merge does not create copies.

<sup>11</sup> HPSG uses feature structure inheritance and typing to factor out commonalities between sub-constructions. For example, subject relatives with overt wh-relatives are specified as wh-subj-rel-cl with constraints inherited from both general clause structure, viz. hd-subj-ph, and relatives in general, viz. wh-rel-cl. Similarly, object relatives, e.g. fin-wh-fill-rel-cl, inherit constraints from wh-rel-cl and general gap structures, viz. hd-fill-ph.

<sup>12</sup> English relative clauses are a complex construction in the sense that there are many exceptions and restrictions, e.g. between subject and object relatives. Simplicity of theory and the elimination of redundancy are what both HPSG and Chomsky’s MP aim for. Despite these common goals, it is perhaps telling that both frameworks are quite complicated. In fact, Sag (1997, 453-454) mentions “every constraint ... is playing some role in this representation, making the combined effect ... a rather intricate theorem.”

In Chomsky (2000), agreement is implemented using (mostly) local c-command between a *probe* and a *goal*. A probe searches top-down into its c-command domain. T (tense), a probe, has *unvalued* phi-features (person, number, gender) that must match *valued* phi-features on the goal. For example, in  $\{T, \{DP, \{v^*, \{V, DP\}\}\}\}$ , T finds the first DP, the subject. Similarly, unvalued phi-features on  $v^*$ , a probe, match corresponding valued features on the DP object. Implicit in this model is that features that remain unvalued will crash a derivation. In this paper, we use  $uF$  to represent unvalued F, F a feature: e.g.,  $uT$  will be an unvalued T feature that needs to be valued in the course of a syntactic derivation.<sup>13</sup>

In our model, movement is generally considered to be feature driven.<sup>14</sup> Heads may have an Edge Feature (EF) that permits movement to the edge of a phrase. For example, in (3)a, the EF on T results in movement of a subject from a  $v^*P$  internal position to the edge of TP, and an EF on an interrogative complementizer,  $C_Q$ , forces movement of a *wh*-phrase to C in (3)b (for visible *wh*-movement).

- (3) a) I  $T_{[EF]}$  read I  $v^*$  the book.  
 b) What  $C_{Q[EF]}$  did you read ~~what~~?

We assume that theta-roles are associated with a determiner head D (rather than N).<sup>15</sup> For example, when V Merges with an object DP, V assigns a theta-role to the DP, which lands on the D head of the object.

We also adopt Chomsky's Phase Theory (Chomsky 2001). Assuming **the Phase Impenetrability Condition (PIC), once a phase is complete**, constituents inside the complement of a phase head are invisible to operations (highlighted by underlining below). However, constituents displaced to the edge of a phase may be accessed outside of the phase. Phase heads are usually assumed to be transitive  $v^*$  and C (possibly, also D). Thus  $v^*P$  and CP (highlighted by boldface  $\{..\}$ ) are the phases in (4)a. Cyclic movement must involve iterated displacement

---

<sup>13</sup> Approaches exist that rely on the idea that features are *interpretable* or *uninterpretable*, and *valued* or *unvalued*, so you can have *unvalued interpretable* features (cf. Pesetsky & Torrego 2007). However, since this notion of interpretability/valuation is not crucial to our analysis, we will simply assume that features can be either unvalued or valued, where unvalued features need to be checked and valued via agreement with matching valued features.

<sup>14</sup> In more recent work, e.g. (Chomsky 2013, 2015), IM is considered to be free, i.e. not feature-driven. In our system, we implement a small amount of free Merge in that a single input stream of lexical items can produce multiple structures.

<sup>15</sup> Here, we assume the DP hypothesis (Abney 1987), which is relatively standard in syntactic theory. However, in some theories, theta-roles are associated with nouns and not determiners. In this case, the theta-role would be assigned to the N head and an argument would not be a DP, but rather an NP. See Bruening, Dinh, & Kim (2018) and Bruening (2020) for arguments that N, not D, is not the head of a nominal argument.

through the edge of each phase, as in (4)b.

- (4) a)  $\{C, \{\underline{DP}, \{T, \{\underline{DP}, \{v^*, \{\underline{V}, \underline{DP}\}\}\}\}\}\}$   
 b)  $DP_{wh}, \{C_Q, \{DP, \{T, \{\underline{DP}_{wh}, \{DP, \{v^*, \{V, DP_{wh}\}\}\}\}\}\}\}$

Given the variety of possible feature mechanisms, one should seek to constrain the grammatical feature system that shapes syntactic derivations as much as possible, as suggested by Chomsky’s MP.<sup>16</sup> Formal language theory tells us that Turing-computability, i.e. arbitrarily powerful devices, can be built on formal features (see Black (1986) and Johnson (1988)). Use of formal features should be kept to a minimum, and conceptually unnecessary ones should be eliminated from the theory.<sup>17</sup> Narrow syntax may make use of other features relevant to the interfaces. For example, we assume Q (question) and *wh* will be read at the semantic interface, and inflectional Case and phi-features will be read at Spell-Out. However, formal features, e.g. Edge, or its earlier incarnation, the EPP (Extended Projection Principle)<sup>18</sup> or ECM (Exceptional Case Marking), are arguably fundamentally limited to Merge syntax, and therefore should be deleted prior to Interpretation and Externalization.<sup>19</sup> The introduction of new features during the course of a derivation is also not permitted. Examples of such devices from the past include indices, as used in Binding theory, or the  $\gamma$ -feature, from the Barriers framework (Chomsky 1986).<sup>20</sup>

We posit, following fundamental MP assumptions, that there is a one-time selection of heads into a Lexical Array (LA) from the lexicon for Merge, but no explicit staging of features (as in MG, see note 10). In our implementation, the LA is ordered as a queue of heads (for input to Merge) purely for computational convenience.<sup>21</sup>

<sup>16</sup> Chomsky (2011; 2013) suggests that narrow syntax be reduced to general Merge, plus residual probe-goal for Agreement. Formal labeling of phrases is carried out at the interface, and therefore phrasal categories have no formal role in Merge. We note that in some other accounts, e.g. Epstein, Kitahara & Seely (2014), Merge may be conditioned on whether labeling obtains for a phrase.

<sup>17</sup> We make substantial use of an Edge Feature (EF) in this paper. In MP development subsequent to our model, features such as Edge, which regulates the possibility of Merge to the periphery of a phrase, are no longer permitted (or relevant). Instead, movement, i.e. internal Merge, must be unrestricted, and therefore freely available, e.g. see Chomsky (2008) and much work thereafter.

<sup>18</sup> This is basically the requirement that a clause have a subject (Chomsky 1981).

<sup>19</sup> If present, any remaining unvalued formal features will crash the derivation.

<sup>20</sup> Also, in some accounts, e.g. Müller (2011, 122), an Edge Feature (made optionally present) may trigger movement, e.g. for scrambling. Such a device would be ruled out on conceptual (not empirical) grounds.

<sup>21</sup> For example, simplifying somewhat with respect to functional elements, in the case of a simple transitive sentence, the LA encodes object < verb < subject. In principle if the LA is unordered we can form from this LA sentences schematized as “subject verb object” and “object verb subject”. The ordering is for convenience as we seek convergence on our intended sentence only.



## 2 The Basic Model

In this section, we briefly summarize the theoretical aspects underlying our account.

We implement a revised version of Gallego's (2006) relative clause analysis, which builds on work by Pesetsky & Torrego (2001) (henceforth: P&T). P&T propose that nominative case results from a checked uT feature (uT = uninterpretable T) on a head D. The head T locally c-commands the subject DP and checks the DP's uT feature, resulting in nominative case. Embedded C also possesses a uT feature, which can be checked in two ways. One way is by raising T to the edge of C and T checks the uT on C. An alternative way is by raising the subject DP to the edge of CP, in which case the already checked uT on D of the subject checks uT on C. When checked by T, the uT feature on embedded C is pronounced as *that* (e.g., *Mary thinks that Sue will buy the book*; P&T 2001, 373). When a nominative subject raises to the edge of CP to check the uT feature on C (e.g., *Mary thinks Sue will buy the book*), there is no pronunciation of *that*.

Although in principle, two methods for checking the uT feature on C are available, P&T utilize economy to account for *that*-trace effects and the English subject/object wh-movement asymmetry.<sup>22</sup> In principle, multiple Agree operations are possible in this system. Abstractly, in (5)a, uF1 and uF2 on X are checked by Y and W, respectively. In (5)b, Z checks both uF1 and uF2 at once instead. Economy dictates that we prefer a single operation (over multiple operations), and therefore, (5)b over (5)a.

- (5) a) Agree( $X_{[uF1, uF2]}$ ,  $Y_{[F1]}$ ) & Agree( $X_{[uF1, uF2]}$ ,  $W_{[F2]}$ )  
b) Agree( $X_{[uF1, uF2]}$ ,  $Z_{[F1, F2]}$ )

Note that the preference for a single Agree relation over a multiple Agree relation does not make any predictions about the presence of *that* in cases where both are possible, as in (6)a. Note that P&T assume that in constructions in which there is wh-movement out of an embedded clause, there is a uWh feature in a non-interrogative C that hosts a wh-phrase. The uT feature on C can be checked either by T, (6)b, in which case *that* is pronounced. The uT feature can also be checked by the subject, (6), in which case *that* is not pronounced. Therefore, *that* is optional, and there is no preference for or against *that*.

---

<sup>22</sup> This is the requirement for *do* in an object wh-question (e.g., *What did John buy?*) compared to no *do* in a subject wh-question (e.g., *Who bought the book?*).

- (6) a) What did John say (that) Mary will buy? (P&T 2001:370)  
 b) What<sub>i</sub> did John say [<sub>CP</sub> **what<sub>i</sub>** [<sub>r</sub>that]<sub>k</sub>+C<sub>[#T, #Wh]</sub> Mary<sub>j</sub> T<sub>k</sub> will Mary<sub>j</sub> buy **what<sub>i</sub>**?  
 c) **What<sub>i</sub>** did John say [<sub>CP</sub> **what<sub>i</sub>** Mary<sub>j</sub> C<sub>[#T, #Wh]</sub> **Mary<sub>j</sub>** T **Mary<sub>j</sub>** will buy **what<sub>i</sub>**]?

Gallego extends P&T's proposal to relative clauses, i.e. that *that* is the pronunciation of uT in C. In addition, Gallego assumes that a relative clause C has a uRel feature that is checked by a relative DP containing a corresponding iRel (i = interpretable) feature. Economy, following P&T, comes into play if both uT and uRel on C can be checked by a single goal. Gallego's analysis is noteworthy in that it attempts to provide a unified account of relative clause formation and the distribution of *which/who(m)/that/Ø*.

According to Gallego, in (7)a, *who man* originates in the subject position of the clause, from where it moves to the relative CP edge, followed by further movement of *man* to a higher position in the CP. Assume the subject relative D *who* contains both an iRel feature and nominative case. Applying economy, *who* checks both uT and uRel on C via a single Agree relation, as shown in (7)b. There is no pronunciation of *that* crucially because *who*, not T, checks uT on C. (Gallego proposes that uT and uRel have EPP (Extended Projection Principle) subfeatures, a complication that we do not adopt, that forces *who man* to raise to the edge of the CP.) Gallego also proposes that there is an extra projection, referred to as cP, in the left periphery that "introduces a subject of predication (Gallego 2006, 157)." This c has uPhi features with EPP subfeatures. The uPhi probe for matching phi-features that are interpretable, and the uPhi find iPhi on *man* in (7)a–b. The EPP sub-feature of uPhi forces *man* to raise to the edge of the cP. Example (7)a with *that* is blocked by economy: pronunciation of *that* would require uT on C to be checked by T, and uRel on C to be checked by *who*, separately. However, economy dictates *who man* checks both uT and uRel features on C simultaneously.

- (7) a) the man who loves Mary/\*the man who **that** loves Mary  
 b) [DP the [<sub>cP</sub> **man<sub>j</sub>** C<sub>[uPhi,EPP]</sub> [<sub>CP</sub> [<sub>DP</sub> **who man<sub>j</sub>**]<sub>i</sub> C<sub>[uT, EPP]</sub> [<sub>uRel,EPP]</sub> [<sub>DP</sub> **who man<sub>j</sub>**]<sub>i</sub> T [<sub>DP</sub> **who man<sub>j</sub>**]<sub>i</sub> loves Mary]]]] (Adapted from Gallego 2006, 156)

An issue is that Gallego's analysis requires an extra cP projection in the left periphery. It is also not entirely clear why *c* can attract N from inside of a relative D and not the head of the DP itself, viz. D.

In (8)a, Gallego assumes the subject *boy* contains a null D, and, following Chomsky (2001), that a null D must remain in situ. Furthermore, the uRel on C (conveniently) lacks an

EPP sub-feature so that *uRel* on *C* is checked by *iRel* on null *D* without triggering movement. The *uT*'s EPP sub-feature then causes *T* to raise to *C*, and be pronounced as *that*. (Note that this analysis also implies that the relative DP *boy* does not move to Spec-*T* either, as it has a null *D*.)

(8) a) the boy that called Mary

b) [DP the [<sub>cP</sub> **boy**<sub>j</sub> C<sub>[uPhi,EPP]</sub> [CP **that**<sub>i</sub>+C<sub>[uT,EPP][uRel]</sub> T<sub>i</sub> [DP<sub>DREL</sub> **boy**<sub>j</sub>] called Mary]]]

(Adapted from Gallego 2006, 158)

This analysis has two potential problems. First, it requires a stipulation that a relative DP with a null *D* cannot move. Furthermore, there is lexical proliferation for *C* containing *uRel*. As *uRel* typically has an EPP sub-feature, this must be modified for relatives containing a null *D*, as they do not move in Gallego's account. Therefore, *C* with *uRel* must come in two versions: one with an EPP subfeature (as in (7)b) and one without an EPP sub-feature (as in (8)b).

Gallego's analysis is also unable to account for the ill-formedness of (9)a; it has difficulty accounting for doubly filled Comp effects. As the structure (9)b indicates, *T* should be able to check *uT* on *C*, resulting in pronunciation of *that*. Because the relative DP is an object, it does not have nominative case, and thus it is unable to check *uT* on *C*. Hence, *that* must be pronounced, as in (9)a. But (9)a is ungrammatical in standard English.

(9) a) \*The car which that John sold. (Gallego 2006, 160)

b) [DP the [<sub>cP</sub> car<sub>j</sub> C<sub>[uPhi,EPP]</sub> [CP[DP which car<sub>j</sub>]<sub>i</sub> that<sub>k</sub>+C<sub>[uT,EPP][uRel,EPP]</sub> John<sub>z</sub> T<sub>k</sub> John<sub>z</sub> sold [DP which car<sub>j</sub>]<sub>i</sub> ]]]]

We adopt a modified version of Gallego's core proposals about *uT* feature checking on a relative *C* and about economy. While we follow Gallego's insights regarding *uT* and *uRel* feature checking, we omit the extra *cP* projection and we do not utilize EPP subfeatures. We are able to account for the distribution of the relative *D* and a noun in the examples above, including the ban on \**who that* in (7). Also contrary to Gallego, we have no stipulation that a DP with a null *D* is unable to move. Our analysis, to be discussed below, is able to account for the ill-formedness of (9)a, and we also extend this analysis to account for headless relatives (which Gallego does not investigate) and genitive relatives, as well as other related relative clause types. Note that we assume the judgments of standard English about relative clauses; in particular, no doubly filled COMP. However, there are varieties of English that permit a doubly

filled Comp, suggesting there may be some dialectical variation in whether or not a relative D can check a uT feature. We discuss this in detail in Section 5.

Suppose all relative D heads check a uRel feature. We assume there is variation in whether or not a relative D may also check a uT feature on C. When relative D can check both a uRel and uT feature, pronunciation of *that* (only when uT on C is checked by T) is blocked due to economy. Only when relative D is unable to check uT on C, then T can (raise and) check uT on C and *that* can be pronounced. Finally, we use an unvalued D feature to trigger extraction of the relative noun, termed “relabeling” in Cecchetto & Donati (2015).

Consider sentence (10)a and its subject relative counterpart in (10)b.

- (10) a) the boy told the story  
b) the boy who told the story

(10)a has the core structure shown in Figure 1, typically assumed in Minimalist syntax.<sup>23</sup> Root *tell* selects for an internal argument, *the story*, and transitive  $v^*$  combines with the phrase headed by *tell* to form a basic verb phrase. Case-Agreement proceeds by minimal c-command. For example,  $v^*$  c-commands and values accusative Case on the internal argument.  $v^*$  also provides for an external argument position in its specifier, occupied by *the boy*.  $T_{\text{past}}$  selects for  $v^*P$  and c-commands the external argument, valuing nominative Case. In English,  $T_{\text{past}}$  also provides for a surface subject position that must be filled, the so-called EPP property. In Figure 1b, *the boy* raises to the edge of TP. Only the highest copy is pronounced, unpronounced copies are indicated by strikethrough. As part of Case-Agreement,  $T_{\text{past}}$  picks up number and person feature values associated with the external argument, resulting in English subject-verb agreement. The heads  $T_{\text{past}}$ ,  $v^*$ , and the root *tell* combine at Spellout to form *told*. (Note: we indicate C as c,  $C_{\text{rel}}$  as  $c_{\text{rel}}$ , and the relative determiner  $D_{\text{rel}}$  as  $d_{\text{rel}}$  in our diagrams.)

---

<sup>23</sup> This can be interpreted as a reduced form of *the boy who was told the story*, as pointed out by a reviewer. In our implementation, the full passive would be constructed, and rules of ellipsis (not implemented) would have to apply. An anonymous reviewer points out that in non-standard varieties of English this could also be interpreted as a subject relative (*the boy ~~who~~ told the story*). See Section 5 for further discussion.

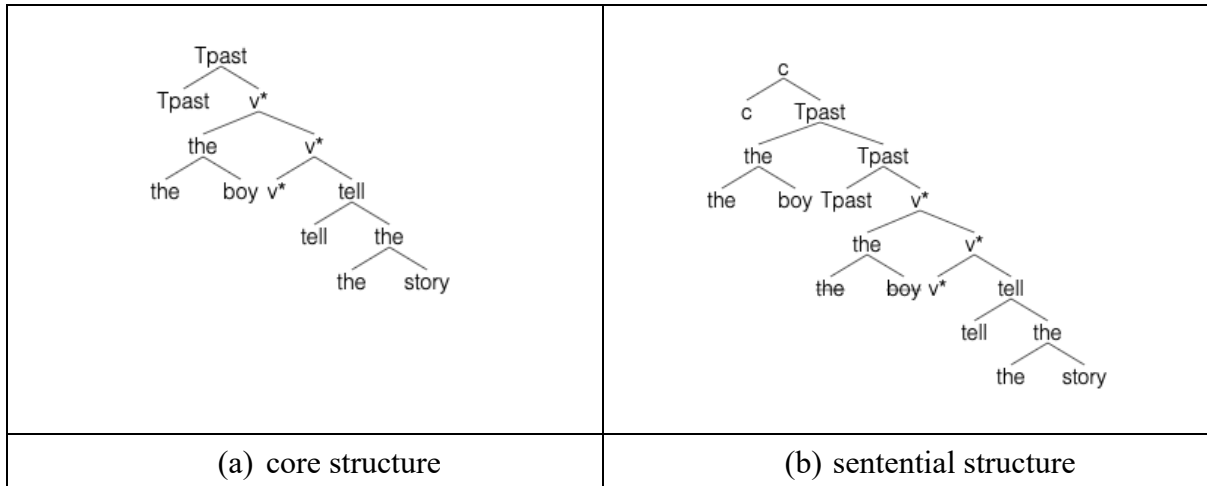


Figure 1 Example of syntactic structure for *the boy told the story*

Example (10)b has the same underlying core as (10)a, with two crucial featural differences that will drive relativization. We assume *rel* to be a formal feature marking the DP that undergoes relativization, which is the external argument headed by *who<sub>rel</sub>* in Figure 2. The clausal head  $C_{rel}$  attracts this external argument (containing *rel*) to its edge. We crucially assume the noun *boy* has an unchecked D feature (uD), indicated by !D, normally checked through Merge with a determiner D. We assume all (and only) relative Ds lack the ability to check uD. Thus, *boy* may subsequently emerge from sentential structure to head a new noun phrase, and its unchecked D-feature will be checked by the (regular) determiner *the*, as shown in Figure 3.<sup>24</sup> As only the highest copy may be pronounced, vertical lines in Figure 3 are used to pick out possible pronounced elements of the frontier of the structure.<sup>25</sup>

<sup>24</sup> A reviewer points out that the following examples require lexical substitution when the head noun is raised out of sentential structure.

(i) *He rode twenty miles to see her picture in the house of a stranger, which stranger politely insisted on his acceptance of it* (Radford 2019, 9)

(ii) *He had hired a vessel to convey him to Constantinople, for which city he should sail in a few hours* (Mary Shelley, *Frankenstein*)

We put aside implementation of a theory of inserting lexical items into a lexical array for future work.

<sup>25</sup> We assume  $C_{rel}$  has no spellout in English. *That* as in the object relative construction *the story that the boy told* is derived via T to C movement, following P&T. See the following sections for details.

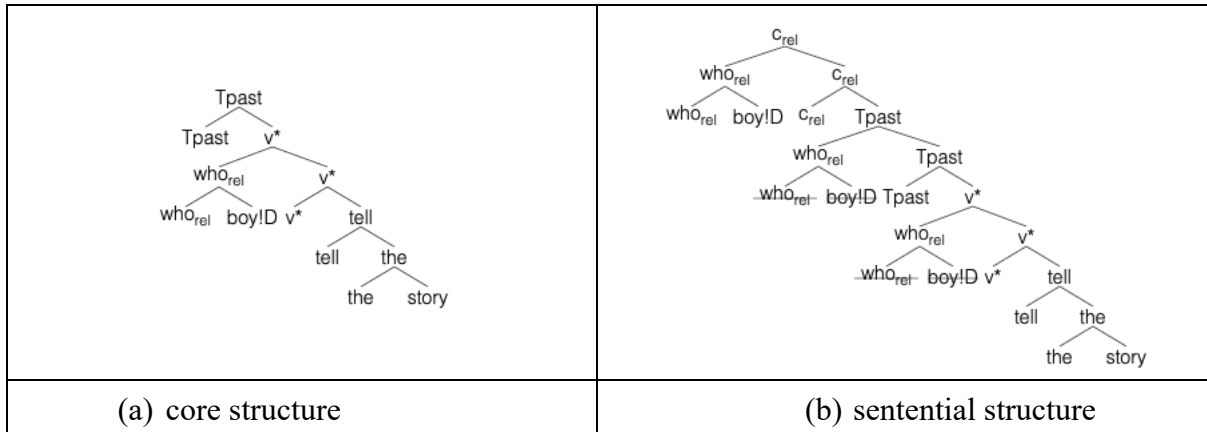


Figure 2 Relative clause structure for *the boy who told the story*

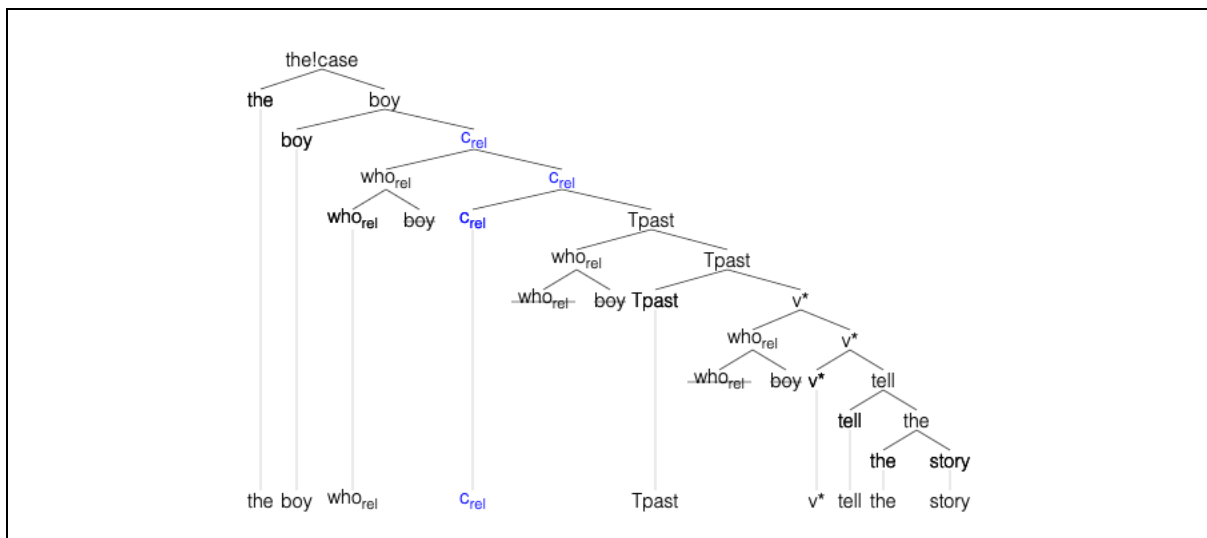


Figure 3 DP structure for *the boy who told the story*

To summarize, uD on N, if left unchecked, enables N to (raise and) relabel a relative clause. N then get its uD feature checked by a higher D in a regular sentence. The feature checking details regarding uD, uT and uRel are summarized in Table 2.

Feature	Checked by
uD on N	iD of D (D <sub>rel</sub> is unable to check uD)
uT	T (pronounced as <i>that</i> ), by nominative case (which is a form of T), or by certain relative Ds
uRel on C <sub>rel</sub>	iRel of D <sub>rel</sub>

Table 2: Feature checking

A reviewer asks how examples such as (11) in which the relative *book on syntax*, not a simple head, can be accounted for under this relabeling proposal. As the PP *on syntax* is an adjunct, the relevant structure is  $\langle \text{book}, \{\text{on}, \text{syntax}\} \rangle$ , where *book* and the PP *on syntax* are pair-Merged, as indicated by the angle brackets. Since pair-Merge is asymmetric, the adjunct *on syntax* is essentially invisible, and *book on syntax* is treated exactly the same as the single head *book*; thus it can relabel.<sup>26</sup>

(11) the [book on syntax] that I read

Relativization productively occurs with external and internal arguments, and even oblique, i.e. non-core, arguments, as will be illustrated in the following sections. In each case, the mechanism is the same, i.e. a relative determiner ( $D_{\text{rel}}$ ) heading the argument to be relativized is attracted by a relative complementizer ( $C_{\text{rel}}$ ). There is no theta role clash (or theta criterion violation) with this movement-based account as we assume theta roles are hosted in D.<sup>27</sup> In Figure 3, external *the* (not *boy*) bears the theta role assigned to the entire DP when it is Merged as an argument in a higher clause, and the lowest copy of *who<sub>rel</sub>* (not *boy*) bears the theta role assigned to the external argument of *tell*. As *the* and *who<sub>rel</sub>* are distinct, there is no theta problem.

We next summarize the algorithm used to derive the structure in Figure 1 above. Assume all sentences involve a selection of heads from the Lexicon to feed Merge. A head may bear both formal features, e.g. D and Case on nominals (discussed above), and unvalued phi-features (person, number in English) on T and  $v^*$ . Unvalued formal features must be valued in the course of a derivation (or else the derivation will not converge). Heads may also bear interpretable features, e.g. Q on *wh*-words and intrinsic phi-features on nominals, e.g. 1<sup>st</sup>-person-singular on *I/me*. A head that probes for matching values gets only one opportunity to value its unvalued formal features, viz. when it is first Merged. If a head H Merges with a phrase YP, as in  $HP = \{H, YP\}$ , YP is the c-command search domain for H's formal features.

---

<sup>26</sup> We suggest the entire pair-Merged structure raises like a head; we cannot have *\*book that on syntax I read*. A reviewer asks about how labeling occurs in an example such as *the destruction of the city that led to the collapse of the empire surprised the traders*. Just as with the VP *destroy the city*, *destroy* cannot separate (by raising) from its argument to form an entirely new phrase. The same applies to the derived nominal form *destruction*, we cannot form *\*the destruction that of the city led to the collapse of the empire*. The entire head with object *the city* must raise and relabel. (In terms of labeling theory, left to future work, both *book on syntax* and *destruction of the city* must be labeled as N.)

<sup>27</sup> Alternatively, assume that a nominal consists of a root R that is categorized by a N categorizer, i.e.  $\{N, R\}$  (cf. Marantz 1997, Chomsky 2013, 2015 among others), and that R can raise independently and be categorized anew. In *the boy who told the story*, the root *boy* alone can raise and relabel the clause, as shown in (i). With two Ns, theta-roles can be assigned independently, without violating the Theta Criterion.

(i)  $[N_2 \text{ boy } [C_{\text{rel}} [\text{who}_{\text{rel}} N_1 \text{ boy}] \dots]]$

Once HP is Merged with another head or phrase, H is inactivated as a probe and cannot search again. As this policy is strict, leftover unvalued features on H will crash the computation, and no convergent structure will be produced.

As the algorithm selects only the first head of a sequence for Merge, heads selected from the Lexicon are sequenced precisely for proper assembly.<sup>28</sup> For (10)a, the sequence of heads that derives the structure shown in Figure 1 is given in (12)a.

- (12) a) [story, the, tell, v\*, [the, boy], T<sub>past</sub>, C]  
 b) [story, the, tell, v\*, [who<sub>rel</sub>, boy], T<sub>past</sub>, C<sub>rel</sub>, the]

Sequence (12)a is read from left to right with the algorithm selecting the appropriate Merge action based on the current state, i.e. the SO (Syntactic Object) constructed so far and the first input head.<sup>29</sup> In most cases, there will be only one possible Merge action per state. Non-determinism, i.e. more than one possible Merge action, is limited solely to linguistic choice points; e.g. the option to pied-pipe a preposition with a DP in English or the T-to-C option described in this paper, both producing derivations that separately converge.<sup>30</sup> Let us sketch the steps for Figure 1: step (i) Merge combines *story* and *the*, forming a DP; (ii) *tell*, the next head in the list, Merges with the DP formed in (i), we obtain {tell, {the, story}} (a VP); (iii) the next head, v\*, Merges with the VP from (ii), forming {v\*, VP}; (iv) the sub-list [the, boy] initiates a sub-computation producing {the, boy}, which replaces [the, boy] in the list of heads, (v) the v\* phrase in (iii) Merges with {the, boy}, the External Argument (EA), forming {EA, {v\*, VP}} (a v\*P); (vi) the head T<sub>past</sub> Merges with the v\*P from (v), forming {T<sub>past</sub>, v\*P}; (vii) English T has an Edge feature (EF) which triggers internal Merge for {T<sub>past</sub>, v\*P}. By minimal search, EA, being the highest accessible DP, is raised, forming {EA, {T<sub>past</sub>, v\*P}}. In step (viii), the last head, C, Merges to head the clause. Note there is no ambiguity as to which sub-phrase must label the merged structure at each step. Therefore, the derivation is deterministic (and efficient in this sense). Minimal search itself is implemented using a stack to maximize the

<sup>28</sup> We must be careful to distinguish this from feature sequencing. In MG, lexical features must be sequenced in strict order for checking. In our implementation, this is not required.

<sup>29</sup> For example, if we merge a D to a N, our algorithm specifies that a DP must result. Similarly, a verbal root and existing DP forms a VP. In each case, we generally know which Merge item must project. For internal Merge, a sub-phrase must be extracted, but the original phrase will generally continue to project, e.g. as in the case {EA, {T, {EA, {v\*, VP}}}}, where EA is an external argument.

<sup>30</sup> Another case involves temporary structural ambiguity in the case of adjunct phrases, which may or may not front, e.g. as in *Yesterday, I went home vs. I went home yesterday*. In such cases, the algorithm considers both possibilities for Merge of the adjunct phrase in turn, but as they are mutually exclusive options, only one of them will be licit (the other will crash). See example (16) in the Appendix.



efficiency of search. Phrases with unvalued features (or *rel*) are placed onto a stack when Merged initially. When Internal Merge is triggered or a head probes to value unvalued features, generally only the top stack element is consulted. For Internal Merge, the top stack element is extracted, i.e. raised. As a goal, the top stack element features must be used (to satisfy the probe). Hence, minimal search typically involves no search at all and minimal c-command naturally results.<sup>31</sup> The derivation of Figure 3 proceeds similarly with the sequence of heads in (12)b. One crucial difference between (12)a and (12)b is that  $C_{rel}$  in (12)b possesses EF, triggering Internal Merge after the equivalent of step (viii), and the EA { $who_{rel}$ , boy} raises (in similar fashion to *wh*-phrase fronting triggered by  $C_Q$ ).

The system that we implemented is based on the feature-driven Merge model of Chomsky (2000, 2001, 2008, and other work).<sup>32</sup> In this work, Chomsky assumes there is a one-time selection of items from the Lexicon to form a Lexical Array (LA). Merge of Lexical Items is recursively applied to form an aggregate SO. An SO can be selected and Merged from the Lexical Array (External Merge) or it can be Merged from within the current SO; this is the process of movement (Internal Merge). The term Workspace refers to the LA and SO at any given stage. For a convergent derivation, the Workspace must consist solely of a single SO, with formal features eliminated. Any remaining uninterpretable features in the SO, or leftover LA items, will crash the derivation.

Multiple threads of derivation are in principle possible if there are multiple possible operations, i.e. choice points, at any given point in the derivation. An example of a theoretical choice point that we use is the possibility of uT on C being checked either by movement of T (resulting in pronunciation of *that*) or by nominative case on the subject (in which *that* is not pronounced). In such cases, e.g. “*the man (that) John saw*”, the model correctly generates two different structures starting from the same LA. Another linguistic choice point will permit the option of pied-piping for cases like “*the man to who/whom I talked*” and “*the man who/whom I talked to*”. (Note that we assume that *who* and *whom* are inflectional variants of the same word *who*. Again, two different structures will be generated from the same LA. The model we describe has only linguistic choice points predicted by the theory; there are no temporary ambiguities attributable solely to the algorithm or data structures required. In this sense, our model is maximally efficient with respect to the theory.

---

<sup>31</sup> We state “typically” as there are a few situations in which the top stack item does not possess the feature needed to match a probe, e.g.  $C_{rel}$  could potentially match with any stacked argument. In such cases, the first matching stack item is used. Should no such item exist, the derivation must crash.

<sup>32</sup> See Collins & Stabler (2016) for a formal account of various important notions in the MP that also attempts to make a connection between MGs and the MP.

Assuming we begin, as does Chomsky, with a one-time LA, our LA is selected in order, purely for computational efficiency.<sup>33</sup> As the LA is ordered as a queue, the current SO has the choice of External Merge with the first item in the sequence, or ignoring the LA, the choice of Internal Merge, i.e. selecting a sub-SO from within itself. Based on the current SO and the head currently first in line in the LA, our machine will correctly select the right operation one step at a time to converge on the intended SO. (In the case of non-convergence, the machine will end up in a state with no possible continuation, call this a *crash*.) Lexical items selected from the LA may have unvalued and valued features. In the case of a LA head with an unvalued feature, when it is first Merged to the current SO, it must probe the existing SO for a matching valued feature. For efficiency, we assume all required probing for valued features can be accomplished during this first Merge time; i.e. no second chances are permitted nor needed.<sup>34</sup>

Our model also incorporates an operation of Last Resort that enables an unlicensed relative head to move to the edge of a phase. If heads with remaining unvalued features are not to crash the derivation, the phrases they head must move to the edge of the Phase to save and keep the derivation going. This Last Resort operation happens automatically. A general remark about feature-driven movement is in order at this point: a head with an EF licenses movement to its phrase edge. Without it, movement is not permitted. Hence, for Last Resort to operate, either we must assume all Phases have an optional EF, or movement is generally licensed to all Phase edges.<sup>35</sup>

The model that we created is *complete* in the sense that all convergent derivations are grammatical and all grammatical sentences in this paper are generated. For a summary of the basic operations of our model, please see the Appendix.

### 3 Derivations of Basic Relative Clauses

Our model crucially accounts for the (im)possibility of *that* in a variety of relative clauses. Consider (13), in which *that* can be either pronounced or unpronounced.

---

<sup>33</sup> With respect to LA ordering, see also footnote 21.

<sup>34</sup> Heads may probe just once, when the head is first merged with an existing SO. Heads are not re-visited for probing once merged. As probes cannot re-try searching for goals in this theory, once an SO has been built, no probe operations can take place inside the SO. Single-probing is efficient because there is never any need to search the SO for probes.

<sup>35</sup> An issue is whether the model should require movement to always be triggered by a feature or whether movement should be freely available (without reference to features) in limited cases. The latter option may result in needless overgeneration, i.e. be less efficient, but conceptually it is simpler (and evolutionarily more plausible).

(13) the book **that/Ø** I read (Gallego 2006, 151)

Snapshots of the derivation of (13) with *that* are shown in Figure 4. In Figure 4a, TP is the current SO, and  $C_{rel}$  is about to be Merged from the LA. In Figure 4b,  $C_{rel}$  has been Merged, and its unvalued features  $u_{rel}$  and  $u_T$  have been checked by  $D_{rel}$  and T, respectively.  $u_T$  on  $C_{rel}$ , checked by T, results in pronunciation of *that*. As  $C_{rel}$  possesses an EF, the DP  $\{D_{rel}, book\}$  raises to the edge of CP. We assume  $D_{rel}$  cannot check the D feature on the noun (in this case, *book*), freeing *book* to raise as shown in Figure 4c. *Book* is a head and therefore labels  $\{book, CP\}$ . Finally, the external D is Merged, checking  $u_D$  on *book*. (Note that the diagram correctly indicates Case (shown as !case) is currently unvalued on the external D head *the*. Its Case will be valued via probe-goal agreement when the relative clause is integrated into a larger environment, as in “They like *the book that I read*.”)

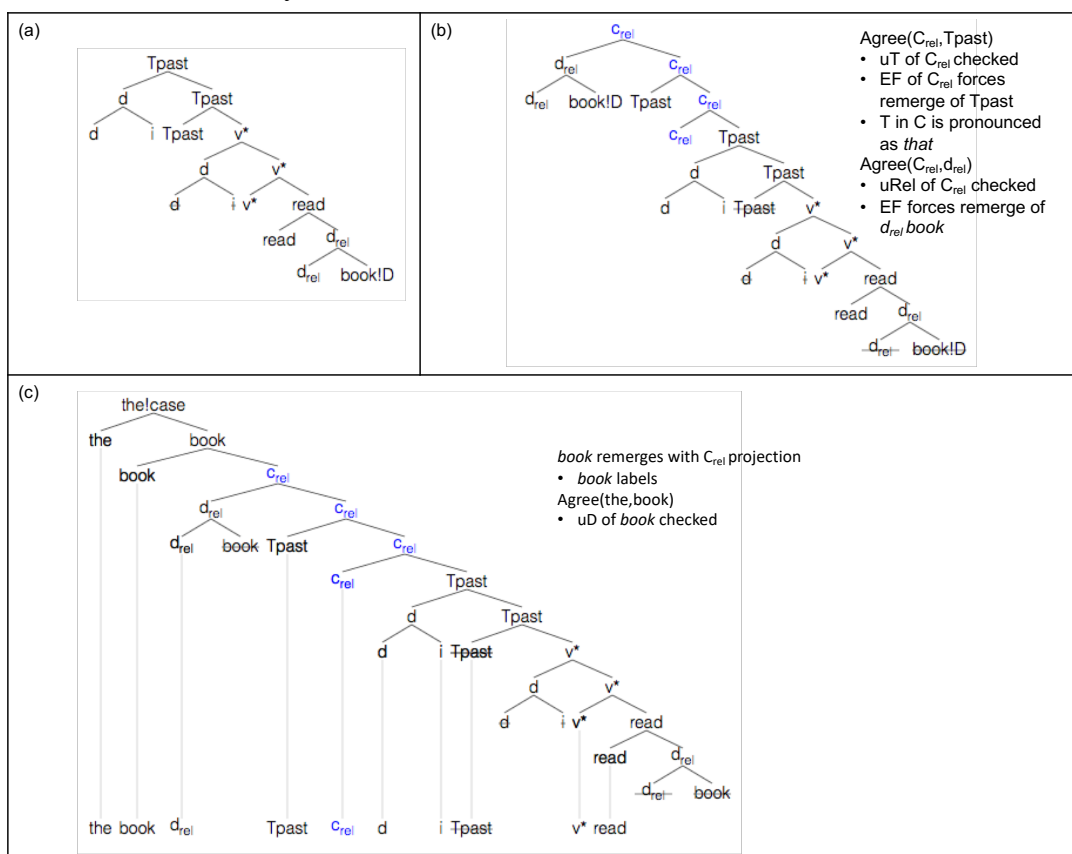


Figure 4 Derivation of *the book that I read*

The corresponding derivation of (13) without *that* is given in Figure 5 – in this case, the option of  $u_T$  being checked by the subject (instead of T) is taken, so *that* is not pronounced. The remainder of the derivation, illustrated in Figure 5a and Figure 5b is the same as in the case with *that*, described earlier.

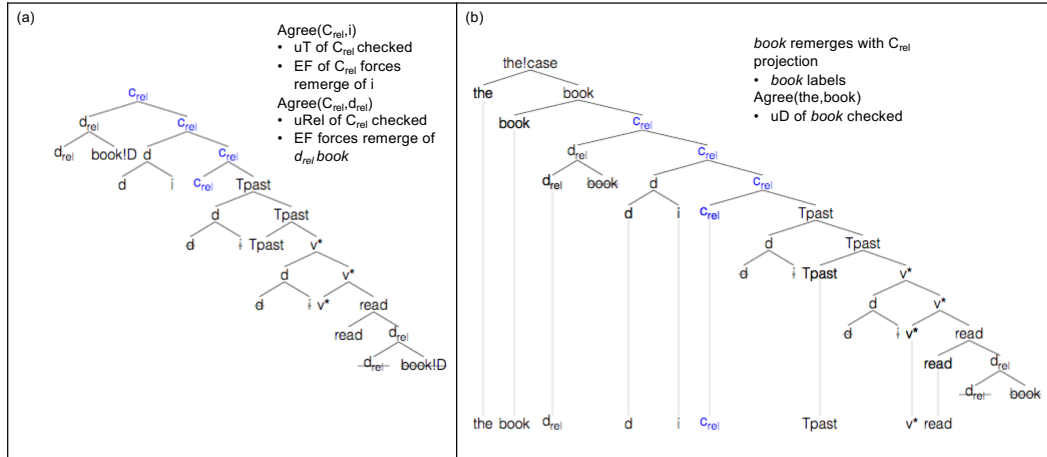


Figure 5 Derivation of *the book Ø I read*

(14) is an example with a covert  $D_{rel}$  within a PP headed by *to*. The two licit derivations are shown in Figure 6 and Figure 7. We assume *talk to* is a verb-particle construction, where *to* is a particle and Case is valued by  $v^*$ .<sup>36</sup> In this case, pied-piping is generally blocked, as *\*the man to that I talked* and *\*the man to I talked* are ill-formed. One explanation for the lack of pied-piping here is that *to* followed by an empty category disallows pied-piping (Chomsky 2001, 28).

(14) the man that/Ø I talked to

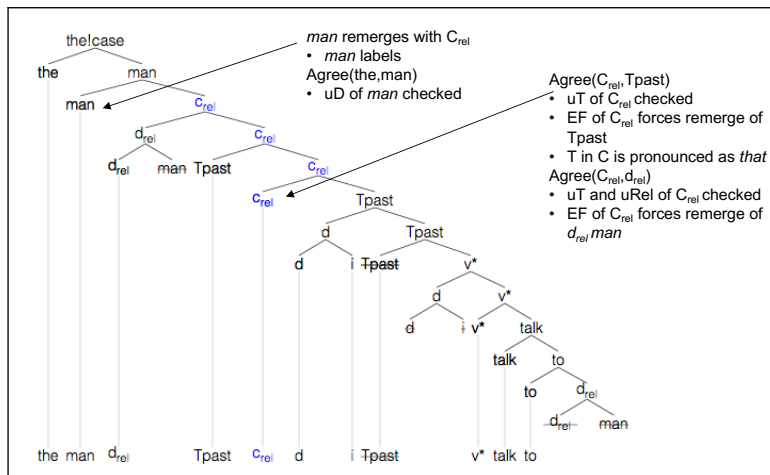


Figure 6 Derivation of *the man that I talked to*

<sup>36</sup> Clearly  $v^* + to$  assigns case. For simplicity of implementation we assume that  $v^*$  assigns Case without *to* mediating it.

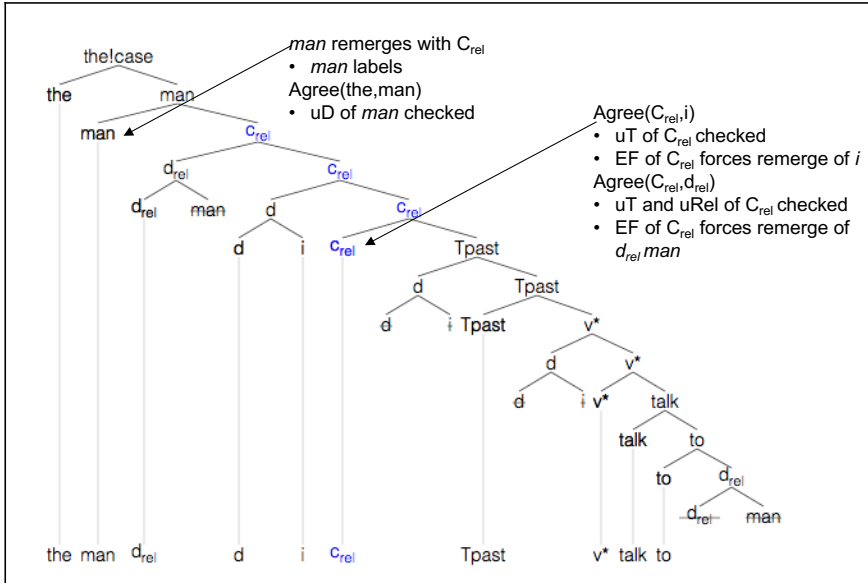


Figure 7 Derivation of *the man Ø I talked to*

Consider the case of the subject relative in (15)a-b.

- (15) a) the boy **that/who** called Mary  
 b) \*the boy called Mary (ill-formed as a relative clause)

In the previous examples, i.e. (13) and (14),  $D_{rel}$  is covert. (15)b can be explained if covert  $D_{rel}$  generally cannot check  $uT$  on  $C_{rel}$ . Then the only available option is for  $T$  to raise to check  $uT$  on  $C$ , obligatorily pronounced as *that* in (15)a, and illustrated in Figure 8.<sup>37</sup> The covert/overt distinction neatly divides  $uT$  (on  $C_{rel}$ ) valuation; in short, covert  $D_{rel}$  cannot check  $uT$  and overt  $D_{rel}$  can. Thus, the *wh*-relative counterpart of (15)b, i.e. *the boy who called Mary*, is available.

<sup>37</sup> For P&T, nominative case is a checked  $T$  feature on an argument, and thus an argument with nominative case can check a  $uT$  feature. However, if certain relative  $D$  heads can check  $uT$ , regardless of whether or not they have nominative case, then the checked  $T$  feature is not necessarily associated with just nominative case. One possibility is that this  $T$  feature-checking ability is associated with case in general, not just nominative case. We leave this issue for further investigation.

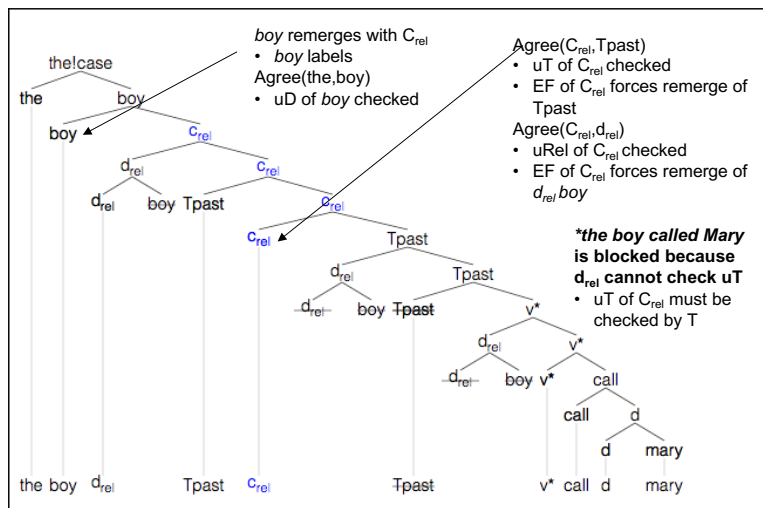


Figure 8 Derivation of *the boy that called Mary*

Our model can also account for long-distance subject relative clauses such as (16)a.

(16) a) the boy (that) John thinks (that) called Mary (*from an anonymous reviewer*)

b) the boy (that) John thinks called Mary

$D_{rel}$  *boy* raises from the subject of embedded verb *call* out to the matrix CP. Since it passes through the edge of the embedded CP, there is no violation of the PIC.  $D_{rel}$  will check the  $uRel$  feature on  $C_{rel}$  at the matrix CP. However, in our theory, the  $uT$  feature on  $C_{rel}$  cannot be checked by  $D_{rel}$ , leaving it to be checked either by movement of the matrix subject to C, as in Figure 9, without the higher *that*, or by T-to-C, pronounced as the higher *that*, as in Figure 10. In the case of the embedded (non-relative) C, viz.  $C_e$ , the lower *that* is predicted to be obligatory because  $D_{rel}$  from  $D_{rel}$  *boy* cannot check  $C_e$ 's  $uT$  feature as it passes through the edge of embedded CP. One of the authors of this paper finds (16)b, which lacks *that* in the embedded clause, to be ill-formed. The other author finds (16)b perfectly acceptable. (Both authors are native speakers of English). This suggests for those who find (16)b fine,  $D_{rel}$  can check the  $uT$  feature of an embedded non-relative C, and for other speakers,  $D_{rel}$  can never check a  $uT$  feature.

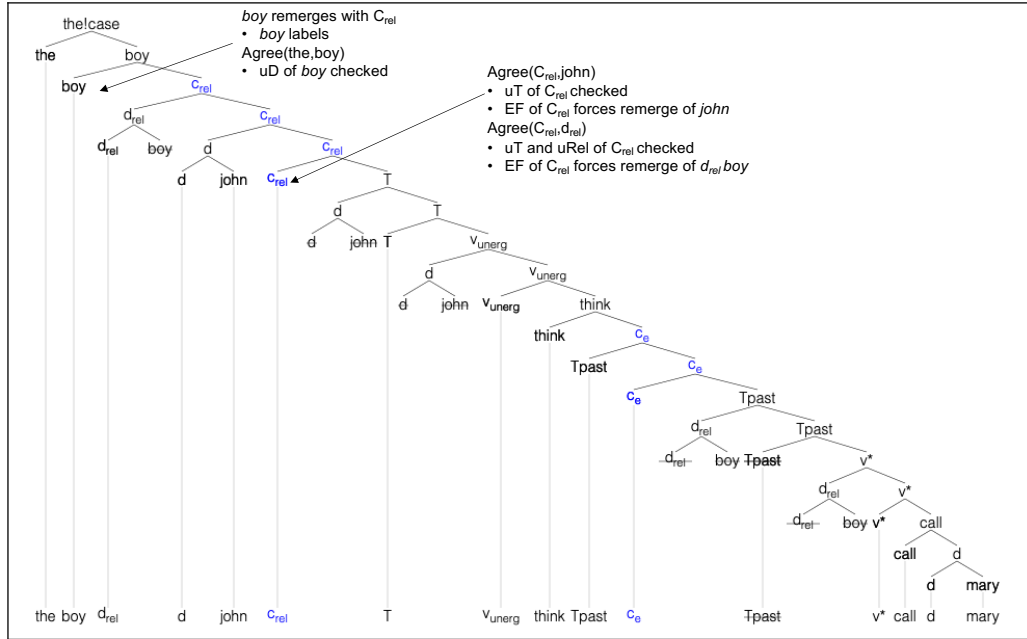


Figure 9 Derivation of *the boy John thinks that called Mary*

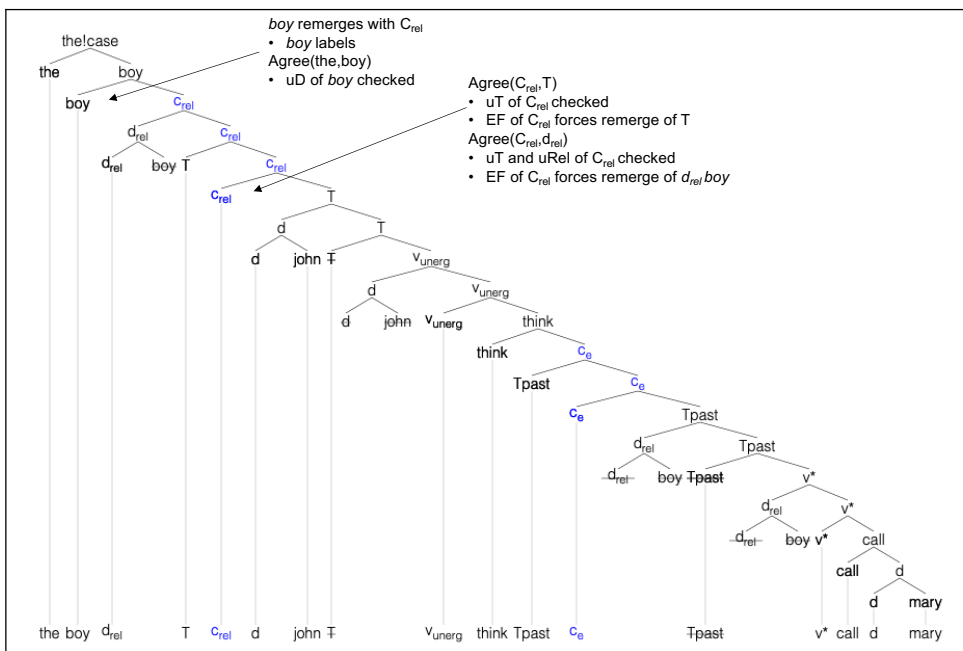


Figure 10 Derivation of *the boy that John thinks that called Mary*

We next consider why a wh-relativizer (e.g. *which*, *who*) cannot co-occur with *that* in an object relative clause (17)a-d, nor in a subject relative clause (17)e-f.

(17) a) the book which I read

b) \*the book **which that** I read (Gallego 2006, 151)

- c) The man who John saw
- d) \*the man **who that** John saw (Gallego 2006, 154)
- e) the man who loves Mary
- f) \*the man **who that** loves Mary (Gallego 2006, 151)

Our proposal is that *which<sub>rel</sub>* and *who<sub>rel</sub>* are relative Ds that may value uT on  $C_{rel}$ .<sup>38</sup> Economy then forces uT on  $C_{rel}$  to always be checked by a relative *wh*-determiner when present. This is summarized in Table 3, which states that it is more economical for a single goal to value multiple uFs on a probe than it is for multiple goals to value the uFs. Basically, the fewer Agree operations required, the better.

Economy (of feature checking)	Given a head $X_{[uF_1, \dots, uF_n]}$ , $n > 1$ , all $uF_i$ ( $1 \leq i \leq n$ ) probe for a matching goal. Suppose distinct goals $G_1, \dots, G_m$ ( $m \leq n$ ) suffice to value $F_1$ through $F_n$ . A derivation with $m_{min}$ , the fewest number of goals required, blocks all derivations with $m > m_{min}$ goals. <sup>39</sup>
-------------------------------	---

Table 3: Economy

In the derivation of (17)a shown in Figure 11, a single Agree relation between  $C_{rel}$  and *which<sub>rel</sub>* results in simultaneous valuation of both uT and uRel on  $C_{rel}$ . Economy blocks the option in which uRel and uT are separately checked (by *which<sub>rel</sub>* (or *who<sub>rel</sub>*) and nominative Case on the subject, respectively). Hence, (17)b, which would require checking of uT on  $C_{rel}$  by T, is blocked. Similarly, the derivation of (17)c, shown in Figure 12, results from a single Agree relation between  $C_{rel}$  and *who<sub>rel</sub>*, and likewise, (17)d is blocked by economy.

<sup>38</sup> Consider (i)-(iii). P&T account for (i) and (ii) by economy. They assume that a non-interrogative embedded C has a uWh feature when there is a wh-phrase contained within. A subject wh-phrase will check both the uT and uWh features on embedded C (resulting in (i)). Economy therefore blocks T from checking just one feature, viz. uT on embedded C, and *that* is not permitted, i.e. (ii) is ruled out. We have argued that the relative *which* can check a uT feature on relative C. Suppose *which book* could also check the uT on embedded C, then by economy, *that* should not be possible in (iii), contrary to fact. We propose, however, that the *which* in *which person* does not have the properties of a relative D in that it cannot check a uT feature. Thus, the uT on the embedded C must be checked either by movement of a subject, in which case *that* is not pronounced, or by movement of T, in which case *that* is pronounced.

(i) Which person did Mary say bought the book?  
(ii) \*Which person did Mary say that bought the book?  
(iii) Which book did Mary say (that) John bought?

<sup>39</sup> This leaves open, in principle, the possibility of there being simultaneous derivations with  $m_{min}$ . In the cases of uT valuation explored in this paper, this theoretical possibility does not occur.



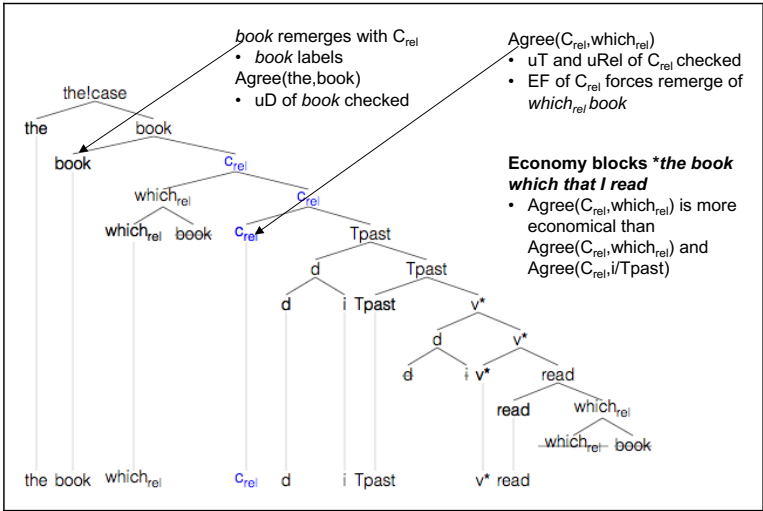


Figure 11 Derivation of *the book which I read*

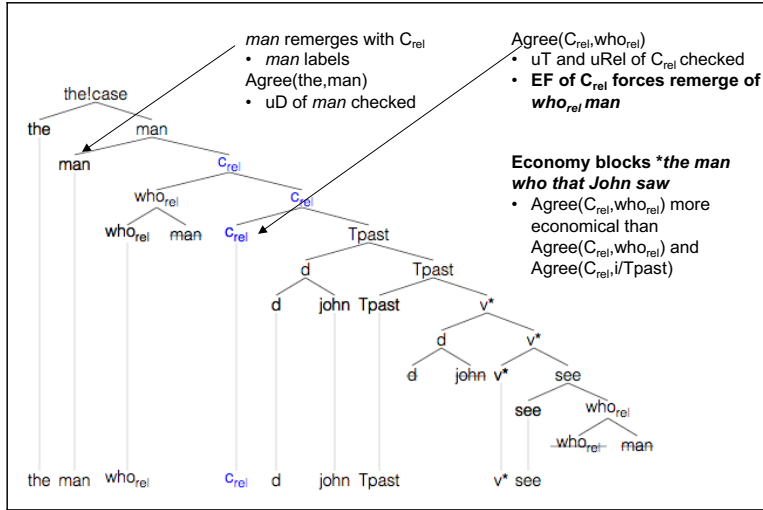


Figure 12 Derivation of *the man who(m) John saw*

Next, consider the case of *who\_rel* in subject relative clauses as shown in (17)e-f. Again, a single Agree relation between *C\_rel* and *who\_rel* licenses (17)e, as depicted in Figure 13, and (17)f is blocked by economy.

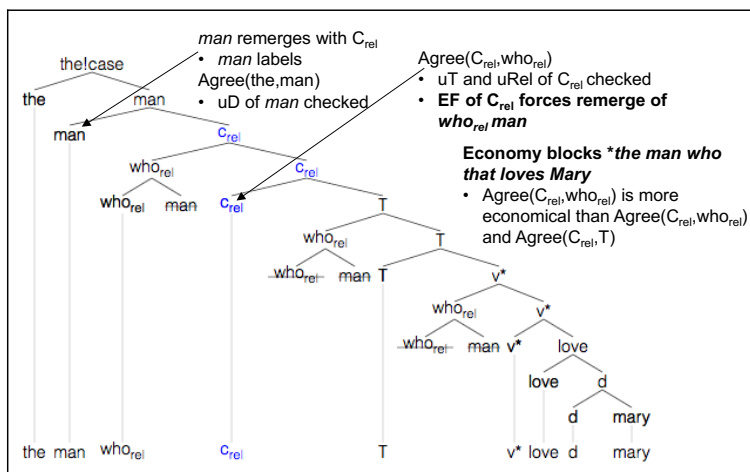


Figure 13 Derivation of *the man who loves Mary*

Related constructions with pied-piping can also be accounted for. Notably, pied-piping of P is optional as shown in (18)a-b, which contain *whom<sub>rel</sub>*, the object equivalent of *who<sub>rel</sub>*. To account for this, we assume that  $C_{rel}$  may Agree with a relative DP contained within a PP, and the EF on  $C_{rel}$  can attract either the relative DP itself or the containing PP. Pied-piping obtains in the latter case.<sup>40</sup>

(18) a) the man whom I talked to (Gallego 2006,152)

b) the man to whom I talked

c) \*the man **whom that** I talked to

d) \*the man to **whom that** I talked

The derivation of (18)a is given in Figure 14. Note we assume *who<sub>rel</sub>* may also be pronounced as *whom* at Spell-Out. For some speakers, the form of *who<sub>rel</sub>* can be sensitive to Case. For example, *whom* = *who*+Accusative.  $C_{rel}$  agrees with the relative DP headed by *who<sub>rel</sub>*, and uT and uRel on  $C_{rel}$  are simultaneously valued. Economy blocks the option of T separately checking uT on  $C_{rel}$ , and (18)c is ruled out. The EF of  $C_{rel}$  attracts the relative DP to the edge of CP, leaving *to* stranded.

<sup>40</sup> A reviewer points out a contrast between the use of *who* versus *whom*, from Radford (1997: 141-142).

(i) a) \*Whom were you talking to?

b) To whom were you talking?

Note that one of the authors finds ia) to be better than ib) and the other author finds ib) to be better. (Both authors are native speakers of English.) As this is clearly a property of dialect, externalization is involved, and Spellout may be sensitive to pied-piping (especially as the pied-piped preposition will be adjacent to *who/whom*). The pronunciation of *who/whom* is not a property of Narrow Syntax.

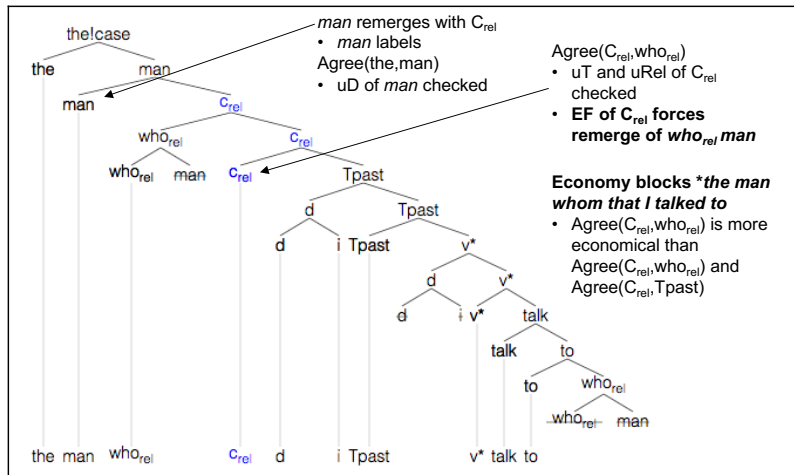


Figure 14 Derivation of *the man who(m) I talked to*

Example (18)b is analyzed in Figure 15. This is identical to Figure 14 except that the entire containing PP is raised to the edge of CP. Similarly, (18)d with *that* is ruled out by economy.

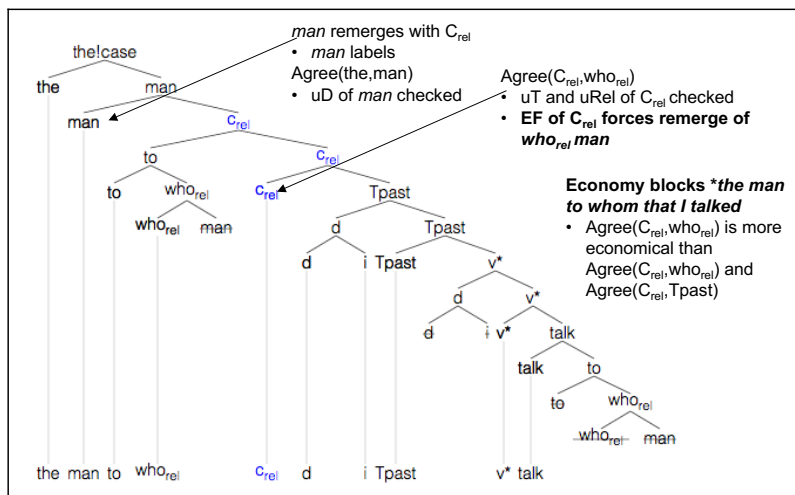


Figure 15 Derivation of *the man to who(m) I talked*

Wh-adverbials such as *when* can also be relativized, as in (19)a-b. Note that *when* and *where* are adverbials, not determiners. We must extend the rel feature to wh-adverbials, *i.e.* *when<sub>rel</sub>* and *where<sub>rel</sub>* exist in the Lexicon. This raises a possible acquisition question as not all determiners have a relative counterpart.<sup>41</sup>

<sup>41</sup> For example, although there is no *the<sub>rel</sub>* in modern English, the Old English demonstrative *se* (sometimes translated as *the*, cf. van Gelderen 2014, 64, 128) can function as a relative determiner (cf. Ringe and Taylor 2014, 444, 447).

- (19) a) the time when I got drunk  
 b) \*the time when that I got drunk

As  $when_{rel}$  has an iRel feature and can check uT on  $C_{rel}$ , our model straightforwardly accounts for (19)a, as shown in Figure 16. We assume that  $when_{rel}$  time initially adjoins at the TP level (as it is a temporal modifier).<sup>42</sup> Furthermore, we assume that  $when_{rel}$  checks both uT and uRel simultaneously on  $C_{rel}$ , so economy blocks (19)b with *that*. Finally, the relative *wh*-adverbial  $when_{rel}$  cannot value the uD of *time* (as is the case with all relative Ds), hence *time* raises and its uD is valued via Merge with external *the*.<sup>43</sup> Other similar examples can be found in the Appendix.<sup>44</sup>

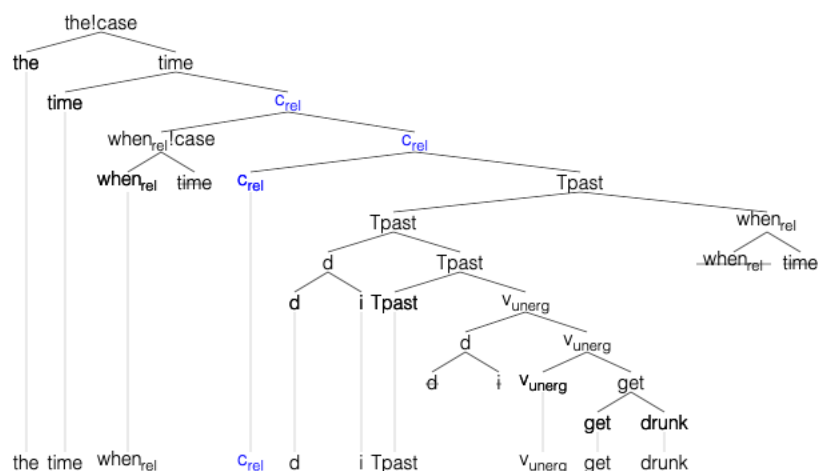


Figure 16 Derivation of *the time when I got drunk*

<sup>42</sup> A reviewer wonders if adverbs can generally take NP complements. We assume all *wh*-adverbs may take an unpronounced in-situ NP complement. Radford (2016, 423) observes that “*when/where/why* have the property that they cannot have an overt nominal complement at PF.”

<sup>43</sup> For further details of this derivation see the Appendix (Example 11). Note that our model tries Merging the adverbial  $when_{rel}$  time using both pair-Merge and set-Merge. Normally, an adjunct would be Merged via pair-Merge only. However, pair-Merge fails because extraction is impossible, assuming that a pair-Merged element is invisible to extraction. As a result, the set-Merge option is required.

<sup>44</sup> A reviewer wonders how we can account for adjectival relatives such as the following:

(i) John will be [however helpful you are willing to be].

Notably, the head of the relative is an adjective, so this could involve relabeling by the adjective *helpful* which then Merges with the adverbial *however*. This is an interesting type of example, which we must leave for future work.

Relatives can also occur in non-finite clauses, as in (20)a-b.<sup>45</sup> Note that Sag (1997) indicates (20)b as being ill-formed; however, we find it grammatical. Pied-piping seems subject to dialectal variation.<sup>46</sup>

- (20) a) the baker in whom to place your trust (Sag 1997, 461)  
 b) the baker whom to place your trust in (Sag 1997, 461 – marked as \* by Sag)

Relevant structures for (20)a-b are given in Figure 17. Note that we employ a non-finite T (Tinf) and a null subject (PRO). We assume a dyadic *in* that takes complement and specifier arguments.

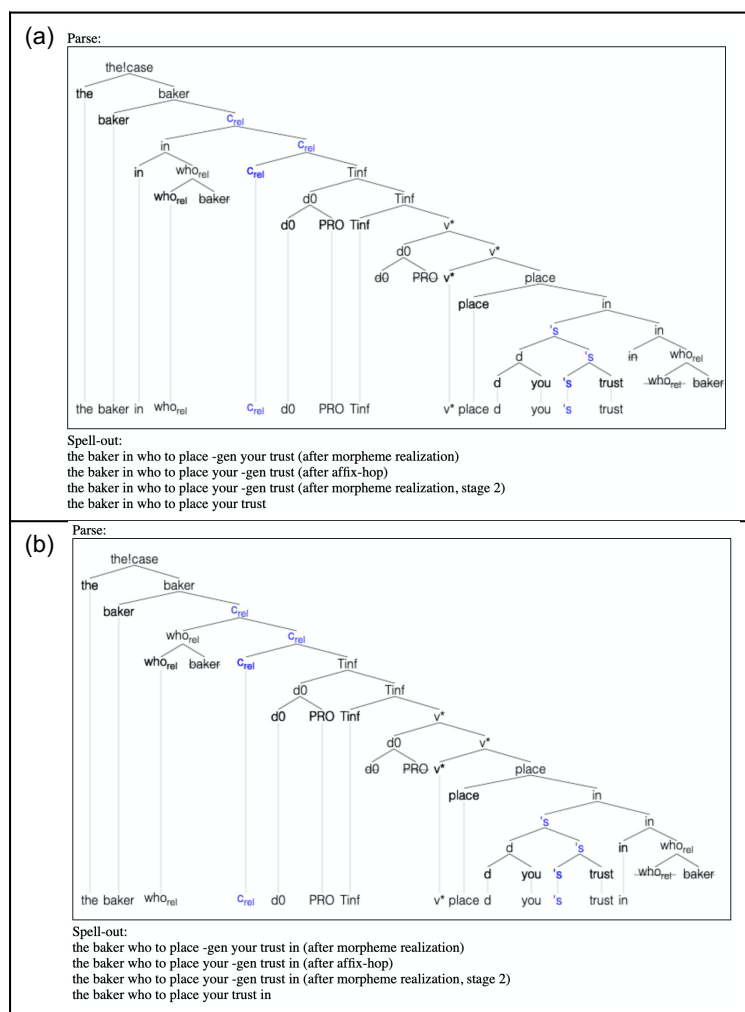


Figure 17 Derivation of *the baker in who to place your trust/the baker who to place your trust in*

<sup>45</sup> We thank a reviewer for questioning how our model can account for this type of example.

<sup>46</sup> A reviewer notes that, in British English, some prefer stranding with *who* and not *whom*.

Another type of non-finite relative clause can occur with an optional *for* as in (21)a–b.

- (21) a) the person to visit  
 b) the person for us to visit (Sag 1997, 464)

Assume that Tinf (as with tensed T) and *for* are both capable of checking the uT feature on C<sub>rel</sub>. For (21)a, as shown in Figure 18, Tinf raises and checks the uT on C<sub>rel</sub>. The noun *person* raises and relabels the clause as a nominal. For (21)b, as shown in Figure 19, we assume that the complementizer *for* raises and checks the uT feature on C<sub>rel</sub>. Since *for* is closer to C<sub>rel</sub> than Tinf, Tinf does not raise given minimal search. The relative DP raises to the edge of CP, and then *person* raises to relabel.

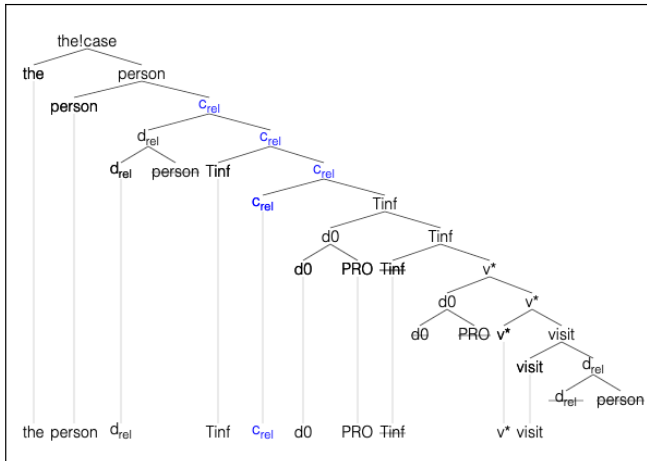


Figure 18 Derivation of *the person to visit*

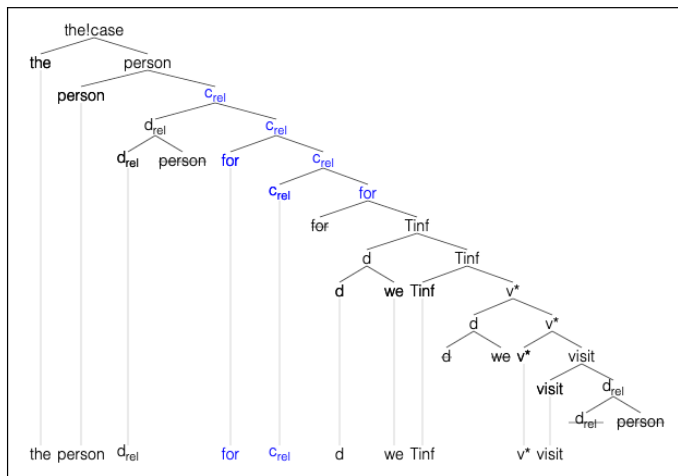


Figure 19 Derivation of *the person for us to visit*

Our analysis also extends to the case of headless relatives, examples shown in (22)a-b. Headless relatives appear not to support *that* for  $C_{rel}$ .

- (22) a) what I read  
 b) \*what that I read

Assume that headless relatives contain  $pro_n$ , a form of *pro* occurring in relative clauses. We can co-opt our  $uRel$  and  $uT$  on  $C_{rel}$  analysis by assuming that  $pro_n$  also has a  $uD$  feature, just as with the overt Ns so far.<sup>47</sup>

Figure 20 illustrates the derivation of (22)a. Suppose a relative determiner  $what_{rel}$ , like  $who_{rel}$  and  $which_{rel}$  previously, agrees with  $C_{rel}$ . In particular, permit  $what_{rel}$  to simultaneously value  $uT$  and  $uRel$  on  $C_{rel}$ . By economy, the option of checking  $uT$  on  $C_{rel}$  separately via  $T$  is blocked, and (22)b is ruled out. Note that we permit  $pro_n$  to undergo movement before Merging with an external null  $D$ . (We do not need to stipulate a difference between covert and overt relative  $N$  with respect to movement.) This null  $D$  values  $uD$  on  $pro_n$ , cf. null  $D_{rel}$ , which cannot value  $uD$ . Finally, we must also assume that  $pro_n$  is limited in distribution to co-occur with relative determiners only, as *\*the what I read* is ill-formed.

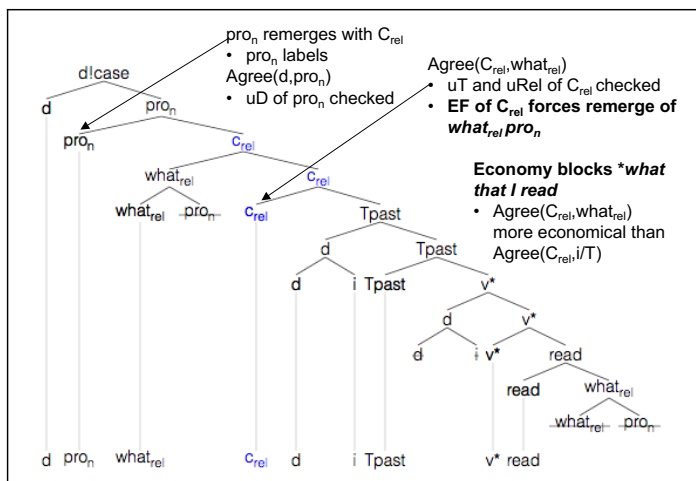


Figure 20 Derivation of *what I read*

<sup>47</sup>  $pro_n$  must have extremely restricted distribution as wh-determiners generally do not occur by themselves. Its use is much more constrained than *pro* in *pro*-drop languages. As a reviewer noted, it's possible to extend this analysis to interrogatives with non-relative *who* and *what* decomposed as *who* + *pro* and *what* + *pro*, respectively, implications of which are not explored here for lack of space.

We next turn to subject headless relative clauses, accounted for in parallel fashion.

- (23) a) what annoys John  
 b) \*what that annoys John

This is similar to the case of (22)a-b, except that the relative DP originates in subject position here. The derivation of (23)a is shown in Figure 21.

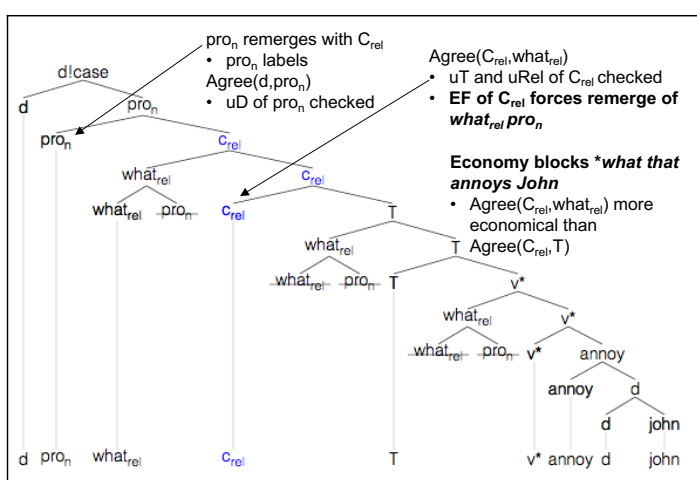


Figure 21 Derivation of *what annoys John*

We have developed an analysis of the distribution of *who/whom/which/what* and a null  $D_{rel}$  in English. The relative determiner *who* occurs with human nouns, with the object variant *whom* occasionally used in some varieties of English.<sup>48</sup> Relative D *which* can be used with **non-human** NPs. A reviewer notes nothing in our syntactic analysis blocks *\*the man which arrived*. We assume semantic feature matching for determiner-noun combinations is also involved, e.g. -human for *which* and +human for *who*. **We assume that the appropriate relative pronoun is selected from the lexicon, so *which<sub>rel</sub>* occurs with a non-human relative noun and *who<sub>rel</sub>* occurs with a human relative noun. (But see also note 3.) Otherwise, these relative Ds are identical.** We have also seen that *what* can be used with a null NP complement.

<sup>48</sup> Radford (2019, 32) writes that “relative *whom/whose* have largely fallen out of use in contemporary colloquial English.” But we note that this does not mean that *whom* is never used. See Radford (2019, 32-33) and references cited therein for discussion of use of *whom* in modern English.



## 4 Comparative and Genitive Relatives

Hale (2003) implemented a Minimalist Grammar that covers a variety of relative clauses from Keenan & Hawkins (1987) involving subject and object relatives, passivization, comparatives, and genitives. Although Hale covers a wide range of relative clause constructions, the reasons for the uses of the relative determiners *which*, *who*, *what*, and for restrictions on their use with *that* are not accounted for. Our model also accounts for all of the relative clause examples from Keenan (1987, 63), notably genitive relatives, as well as other related constructions.

The examples in (24) from Keenan & Hawkins (1987, 63) are essentially identical to examples that we have discussed earlier (Hale models (24)a, b, c, and a version of d).<sup>49</sup> (24)a is a subject relative (see Figure 8 above), (24)b-c are object relatives (see Figure 11 and Figure 12). (24)d-e contain relative nouns that originate as the object of a preposition (as in Figure 14 and Figure 15).<sup>50</sup> See the Appendix for complete derivations of these particular examples.<sup>51</sup>

- (24) a) the boy who told the story – Subject relative  
b) the letter which Dick wrote yesterday – Object relative  
c) the man who Ann gave the present to – Relative object of P  
d) the box which Pat brought the apples in – Relative object of P  
e) the dog which was taught by John – Passivized object relative (Keenan & Hawkins 1987, 63)

---

<sup>49</sup> Instead of (24)d, Hale (2003:98) lists “the box which Pat brought with apples in”, which differs from the original Keenan and Hawkins example in that *apples* is contained within a PP. Some find these examples marginal or unacceptable. We modeled the original example on the assumption it is broadly acceptable.

<sup>50</sup> Although not important for our analysis of relative clauses, in (24)b we assume that the adverbial *yesterday* is a DP that is Merged at the TP level. Note that *yesterday* can behave as a nominal, as in (i-ii). We adopt Larson’s (1985) view that the adverbial *yesterday* is really an NP with inherent case (Larson’s proposal is that if Case isn’t checked, a default case can be assigned to certain temporal NPs).

(i) yesterday’s refusal (Larson 1985:598)

(ii) Yesterday was a great day.

We also follow Haumann’s (2007) view that temporal adverbials like *yesterday* are outside the vP. The ill-formedness of (iii), in which *yesterday* occurs in a TP-internal position, can be accounted for if *yesterday* is Merged at the TP level.

(iii) \*Illicit smokers were yesterday fined for taking a puff. (Haumann 2007, 265)

Similarly, in the following examples adapted from van Gelderen (2013, 127), *yesterday* (van Gelderen uses *last week* instead of *yesterday*), is ill-formed in a TP-internal position, but fine in other positions, that are not necessarily TP-internal.

(iv) a) They were happy yesterday.

b) Yesterday, they were very happy,

c) \*They were yesterday very happy.

See the Appendix for the complete derivation of (24)b.

<sup>51</sup> The passive (16e), as shown in the Appendix, is formed with a v~ and a participle Prt. The v~ is a verbalizing head (Deal 2009, Sobin 2014). Both Prt and v~ have EF subfeatures that force remerger of the relative DP.

We next discuss some examples from Keenan that require some revisions to our core model.<sup>52</sup>

In example (25) below, *boy* originates from a relative DP object of the comparative *than*.<sup>53</sup>

(25) the boy who Mike writes better than (Keenan & Hawkins 1987, 63) – relative object of comparative *than*

As shown in Figure 22, the relative *who<sub>rel</sub> boy* raises and remerges with *C<sub>rel</sub>*, checking *uRel* on *C<sub>rel</sub>*. The head *boy* with unvalued *uD* raises out of *C<sub>rel</sub>P*, then relabels and Merges with external *the* (which checks unvalued *uD* on *boy*).

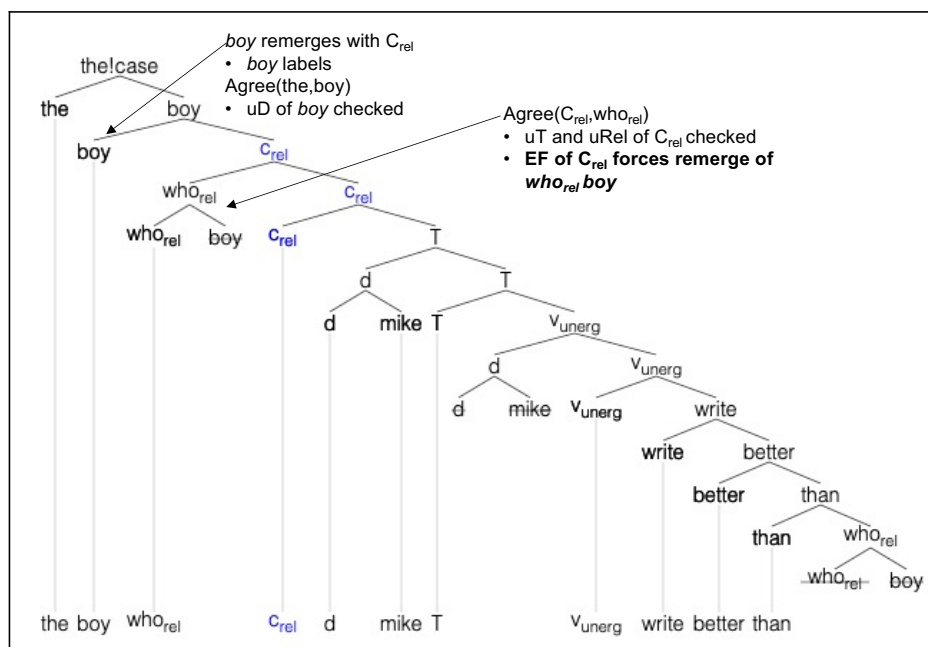


Figure 22 Derivation of *the boy who Mike writes better than*

Next, we consider (26), from Keenan, which contains a genitive subject relative.

(26) the girl whose friends bought the cake – Genitive subject relative (Keenan & Hawkins

<sup>52</sup> Of the following examples, to the best of our knowledge Hale (2003) modeled (26) and (27), but not the other types of examples.

<sup>53</sup> It is crucial for our analysis that *than* has a relative clause DP complement (or that a relative DP occurs within the complement of *than*) in this example. Our analysis may not extend further to other constructions with *than*. One possibility is that *than* can be a P, following Hankamer (1973) and Chomsky (1977).

Figure 23 analyzes (26) as follows: the possessive subject DP  $who_{rel}$  *girl* 's *friend* raises from the edge of  $v^*P$  to the surface subject position at the edge of TP. This is followed by raising to the edge of  $C_{rel}P$  ( $who_{rel}$  checks  $uRel$  on  $C_{rel}$ ). The head *girl* raises and relabels the structure. We need to assume that although  $who_{rel}$  is embedded in the specifier of the possessive DP, its  $Rel$  feature is visible to  $C_{rel}$  and  $Agree(who_{rel}, C_{rel})$  results in raising of the entire DP.<sup>54</sup>

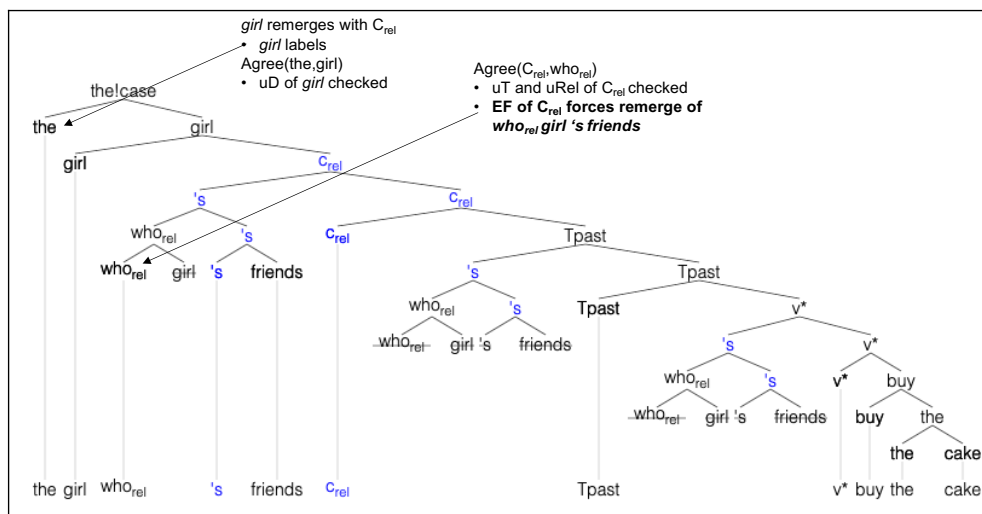


Figure 23 Derivation of *the girl whose friends bought the cake*

Example (27) is similar to (26) except that the genitive relative originates as an object. As shown in Figure 24, the genitive relative raises to the edge of  $C_{rel}P$ , and the head *man* then further raises and relabels.<sup>55</sup>

(27) the man whose house Patrick bought – Genitive object relative (Keenan & Hawkins 1987, 63)

<sup>54</sup> A reviewer asked about the impossibility of *that*-relatives and zero relatives in this case. The derivation for *the girl whose friends* is currently based on:  $[[who_{rel} \text{ girl}] ['s \text{ friends}]]$ . This raises the question of why  $[[d_{rel} \text{ girl}] ['s \text{ friends}]]$  can't be substituted. We assume  $0_{rel} + 's$  is not a possible English word because  $'s$  is an affix and it has to **affix to an overt word** (see Radford 2016, 405-406). **We assume that affixation happens at Spell-Out and is not a syntactic process. It requires an adjacent host with phonological content, so  $d_{rel}$  does not qualify as a host.** In this case, *that* is not permitted because *that*-relative formation requires separate raising of T to C (to check  $uT$  on C) and is blocked by economy (following P&T).

<sup>55</sup> Our model also predicts that T can check a  $uT$  feature on  $C_{rel}$ , resulting in *the man whose house that Patrick bought*, an example that seems well-formed to us. See the Appendix for the complete derivation.

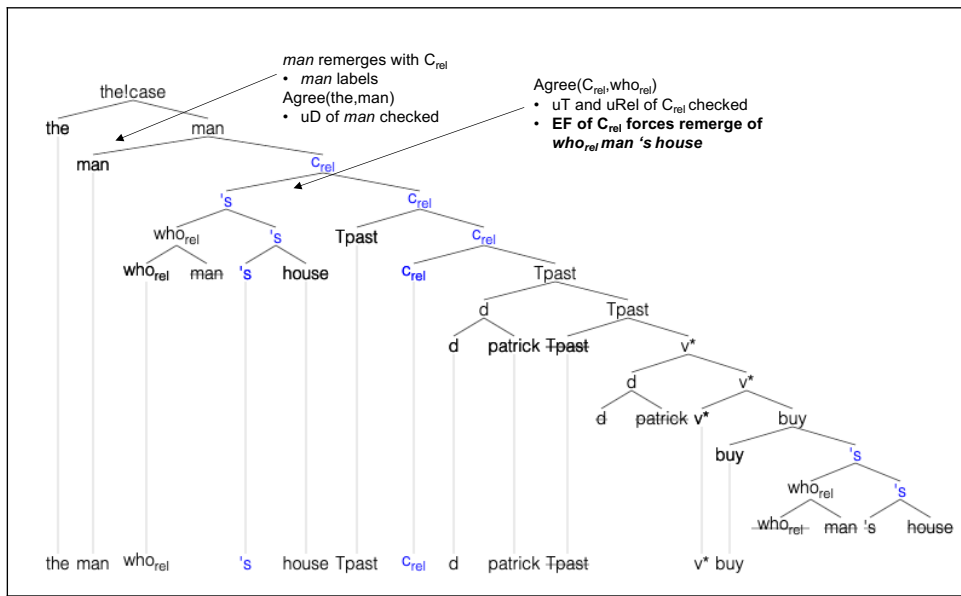


Figure 24 Derivation of *the man whose house Patrick bought*

Example (28) is similar to those shown previously in Figure 22 and Figure 23 except that it is a passive construction (see the Appendix for the complete derivation).

- (28) the boy whose brother was taught by Sandra – Genitive subject of passivized object relative (Keenan & Hawkins 1987, 63)

Note that in addition to these examples from Keenan, our model is also able to generate related relative clause constructions with the relative contained within a PP complement headed by *of*. Examples (29)-(31)a correspond to the genitive relatives (26)-(28) except that the relative pronoun originates in a PP complement headed by *of*.<sup>56</sup>

- (29) a) the girl who friends of bought the cake<sup>57</sup>  
 b) friend of *who<sub>rel</sub> girl*
- (30) a) the man who Patrick bought the house of  
 b) house of *who<sub>rel</sub> man*
- (31) a) the boy who the brother of was taught by Sandra  
 b) brother of *who<sub>rel</sub> boy*

<sup>56</sup> We note, for some speakers, examples such as these are ill-formed.

<sup>57</sup> Culicover (2013:161) provides the following similar example.

(i) a man who friends of *t* think that enemies of *t* are everywhere

The structure of (29)a is shown in Figure 25.

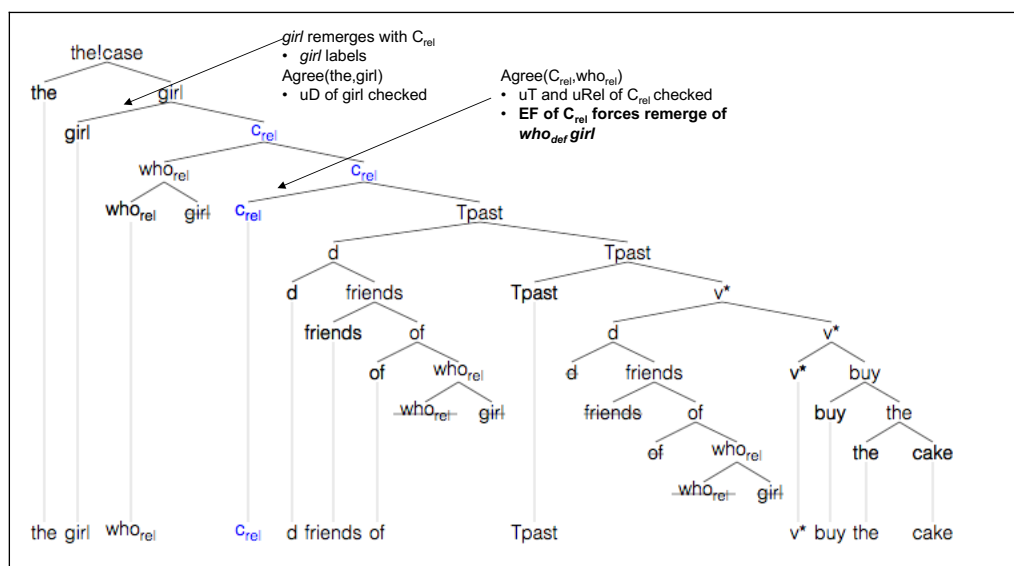


Figure 25 Derivation of *the girl who friends of bought the cake*

The relative DP *who<sub>rel</sub> girl* originates in a PP *of*-phrase that is the complement of *friends*, embedded within the subject. After the subject moves to the TP edge, the relative DP *who<sub>rel</sub> girl* moves to the *C<sub>rel</sub>P* edge to check the *uRel* feature, and head *girl* moves out and relabels. Example (30)a is similar except that it involves a relative object, and (31)a involves a passivized relative object.

We next turn to deeply embedded genitive relatives, such as in (32).

- (32) Give me the phone number of the person whose mother's friend's sister's dog's appearance had offended the audience. (Sag 1997, 450)

The structure of the relative DP *whose person 's mother 's friend 's sister 's dog 's appearance* is shown in Figure 26. In our implementation, we must assume that the relative feature of deeply embedded *who<sub>rel</sub>* percolates up onto the highest 's, so *C<sub>rel</sub>* is able to attract the entire DP to check its *uRel* feature.<sup>58</sup>

<sup>58</sup> A reviewer asks whether the whole relative clause has to be attracted. The whole relative clause must be attracted, which we can see by examining examples of object relativization, shown below. Compare this with cases of pied-piping, where there can be some variation.

- (i) the person [whose mother's friend] the play offended  
 (ii) \*the person whose the play offended [~~whose~~ mother's friend]

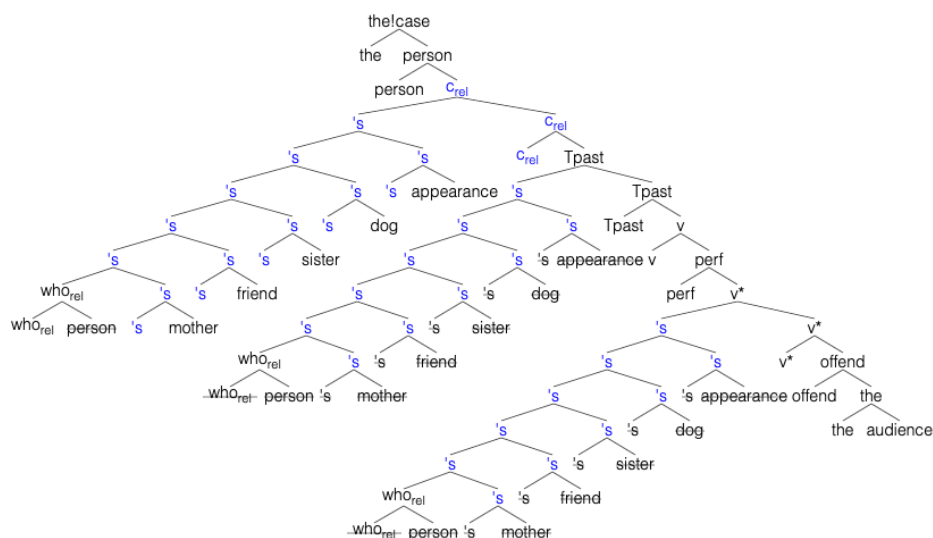


Figure 26 Embedded relative: *the person whose mother's friend's sister's dog's appearance had offended the audience*

See the Appendix for further examples of embedded relatives.

## 5 Other varieties of English

We have focused on an analysis that accounts for the structures of basic relative clauses in modern standard English. Although the relative **clauses'** heads in (33)a-c are unavailable in standard modern English, they do occur in older stages of English and in some modern dialects.

- (33) a) \*which that  
 b) \*who(m) that  
 c) \* $\emptyset$  in a subject relative (e.g., \*the boy called Mary)

Old and Middle English allow a doubly filled CP. Examples (34)a–b below are from Old English. *Se* is a demonstrative pronoun, although it is translated as a *wh*-pronoun (Ringe and Taylor 2014, 467).

- (34) a) *Se [weig se ðe læt to heofonrice] is for ði nearu & sticol*  
 the way which C leads to heaven is therefore narrow and steep

‘the way which leads to heaven is therefore narrow and steep’

b) Hwæt is god butan Gode anum [se þe is healic godnisse]

What is good except God alone who C is sublime goodness

‘what is good except God alone, who is sublime goodness’ (Ringe and Taylor 2014, 468-469).

Examples of *which that* are also attested in Middle English, as shown in (35)a–b and (36) below.

(35) a) they freend **which that** thouh has lorn

‘your friend that you have lost’

b) the conseil **which that** was yeven to yow by the men of lawe and the wise folk

‘the counsel that was given to you by the men of law and the wise folk’ (Penn-Helsinki Parsed Corpus of Middle English - Kroch & Taylor 2000, per Santorini & Kroch 2007, Chapter 11)

(36) the est orisonte, **which that** is clepid comounly the ascendent

the eastern horizon which that is called commonly the ascendant

‘The eastern horizon, which is commonly called the ascendant.’ (Van Gelderen 2014, 128, per Chaucer *Astrolabe* 660. 17-8)

Zero subject relatives may also occur. Examples (37)a–c below are cited by Bauer (1994).

(37) a) It was [the city gave us this job]. (Bauer 1994, 77, per Shannon 1978, 15)

b) Even if I found [somebody knew who I was], I won’t be them no more. (Bauer 1994, 77, per Wolfe 1977, 151)

c) They used to arrest [people did that kind of thing]. (Bauer 1994, 77, per Higgens 1976, 78-79)

Belfast English also has zero subject relatives, as in (38)a–b.

(38) a) There are [people don’t read the books].

b) It’s always [me pays the gas bill]. (Henry 1995, 124)

Finally, the following two examples are from Black English Vernacular/African American English.

(39) Ain't [nobody know about no club] (Labov 1972, 188).<sup>59</sup>

(40) The [man saw John] went to the store. (Sistrunk 2012, 5)

In our analysis so far, we have assumed the Lexicon contains *who<sub>rel</sub>*, *which<sub>rel</sub>*, *when<sub>rel</sub>*, and *what<sub>rel</sub>*, all of which are able to value uT on C<sub>rel</sub>. It is certainly plausible that this property could vary over individual lexical items. Thus, certain varieties of English, *which<sub>rel</sub>* and *who<sub>rel</sub>* may lack this ability, thereby permitting uT on C<sub>rel</sub> to be checked separately by T or nominative Case on a subject, crucially licensing the pronunciation of *that* in the former case. Another point of variation concerns null D<sub>rel</sub>; we proposed earlier that null D<sub>rel</sub>, unlike overt D<sub>rel</sub>, is unable to value uT on C<sub>rel</sub>, but it appears that in some dialects null D<sub>rel</sub> may behave like overt D<sub>rel</sub>, permitting zero subject relatives, e.g. as in Belfast and African American English. To summarize, a relative D must contain a core Rel feature (by definition). However, the ability to value uT on C<sub>rel</sub> may vary diachronically and/or synchronically. **To summarize, this minor change in lexical feature specification can account for the data described above and is not a problem for our computer implementation in principle.**

## 6 Conclusion

We have built our theory and verified implementation based on the insights of Gallego's (2006) analysis of relative clauses. Gallego, in turn, has built on the insights of P&T (2001). The fact that this refinement is possible is a sign that the Minimalist Program is a viable research program. Our account makes use of a relative complementizer (C<sub>rel</sub>) with separate unvalued Rel (relative) and T (Tense) features. Rel is a construction-specific formal feature, distinguishing relatives from normal clauses. Rel and T together are subject to economy considerations, i.e. simultaneous valuation (where possible). Our verified analyses improve upon Gallego in the following ways: a) there is no need for an extra projection in the left periphery, b) there is no stipulation that a null D cannot move, c) there is no need for two types of C, one with an EPP feature, and one without, and d) we are able to account for the absence

---

<sup>59</sup> Labov (1972, 188) gives (i), with a zero subject relative, as a possible underlying structure for this example. However, another possible structure given by Labov is (ii) which does not contain a relative clause.

(i) (It) ain't nobody (that) know about no club.

(ii) Nobody ain't know about no club.



of *which that* in standard English. The additional stipulations of our model are that: i) a relative D cannot check a uD feature on N, in order to trigger extraction of the relative noun for relabeling, and ii) the null  $D_{rel}$  cannot generally check a uT feature, although other relative Ds, such as *which<sub>rel</sub>/who<sub>rel</sub>/whom<sub>rel</sub>/what<sub>rel</sub>/when<sub>rel</sub>*, can. A natural question arises: is our three-feature system, Rel, T and D, minimal, i.e., *parameter-efficient*? As, in our theory, movement is driven, both EF and something akin to our unvalued D are required to initiate raising and relabeling of the relative clause into a nominal. Finally, a minimum of two features, such as Rel and T, is needed in order to exploit economy. Economy simplifies operational complexity, enabling multiple features to be valued in one operation. More broadly, in the MP framework, the functional category T selects for verbal phrase structure and further projects phrase structure (with a surface subject position).<sup>60</sup> In Chomsky (2008), non-selectional properties of T, e.g. phi-features, the ability to value nominative Case and Tense, do not appear in T's lexical entry, but instead are transmitted from phase head C.

Overall, we have developed a detailed and logically consistent feature-driven theory of English relative clauses in the MP framework. We have also built a computer-implemented derivational system capable of converging on the correct analyses starting from an initial LA queue. The implementation confirms that our theory is both complete and detailed enough to constitute an (automatic) computer program. The interested reader is referred to the Appendix, which contains step-by-step computer-generated derivations, too detailed to be included in the main body of the paper. The Appendix includes all the English relative clause examples discussed in the paper (and others). The program is able to correctly select the precise Merge operation at each step (without human intervention), based on the state of the current SO and the first available item in the LA.<sup>61</sup> Moreover, our implementation permits us to verify that the model does not generate spurious analyses - unpredicted by the theory - for all example sentences.

We summarize the core relative D facts in [Table 4](#).

---

<sup>60</sup> It is unclear to us whether the Edge feature of T (the requirement for subjects in English, also known as the EPP in earlier theories) should also be inherited from C.

<sup>61</sup> We note that a machine learning approach has been taken in predicting the correct stack operation to take in transition-based dependency parsing, Nivre (2003), and in subsequent large-scale models, e.g. Andor *et al.* (2016). This is reminiscent of selecting the correct Merge operation to perform in our system.

	Relative D	Features	Explanation	Examples
(a)	D <sub>rel</sub>	Rel	D <sub>rel</sub> unable to value uT. uT on C <sub>rel</sub> must be checked by T if relative DP is a subject.	(14) the man that/Ø I talked to (15)a the boy that called Mary (15)b *the boy called Mary
(b)	which <sub>rel</sub> who <sub>rel</sub> whom <sub>rel</sub> what <sub>rel</sub> when <sub>rel</sub>	Rel, T	which <sub>rel</sub> /who <sub>rel</sub> /whom <sub>rel</sub> / what <sub>rel</sub> /when <sub>rel</sub> can value uT. By economy, uRel and uT on C <sub>rel</sub> must be simultaneously checked by one of the above wh <sub>rel</sub> 's. Note: <i>that</i> is banned	(17)a the book which I read (17)c the man who John saw (17)e the man who loves Mary (19)a the time when I got drunk (22)a what I read (23)a what annoys John (17)b *the book which that I read (17)d *the man who that John saw (17)f *the man who that loves Mary (19)b *the time when that I got drunk (22)b *what that I read (23)b *what that annoys John

Table 4: Summary of relative Ds in English

Finally, we believe our analysis can be extended to account for data in other dialects and languages, assuming limited variation in determiner heads with respect to the ability to value uT on C<sub>rel</sub>. There are also a variety of other relative clause types that remain for future work.<sup>62</sup>

### Abbreviations

C = Complementizer

COMP = Complementizer

cP = (extra) Complementizer Phrase (above the normal CP)

CP = Complementizer Phrase

<sup>62</sup> For example, stacked relatives such as (i) are not accounted for by the system described here. In principle, if we add the *n*-ary operation FormSet of Chomsky (2021), proposed there for unbounded, unstructured coordination, to apply to the stacked relative clauses (each formed separately in its own sub-Workspace), we can form a set of C<sub>rel</sub>P phrases. Then we further require parallel extraction of the nominal head across the members, perhaps justified as the heads are identical inscriptions. In this way, stacked relative clauses can be accommodated. For example, if *student who lives here* and *student who studies English* are constructed in parallel with repetitions of the head noun *student*, (i) can be formed. Each *that* is the pronunciation of T in C. On the other hand, in (ii), assuming that *what* is the same D, it should only be pronounced once, thus ruling out (ii). Compare with (iii), which seems to be well-formed.

(i) the student who lives here who studies English

(ii) \*what I saw what Mary likes what John hates

(iii) what I saw Mary likes John hates

C<sub>Q</sub> = interrogative (Question) complementizer  
 C<sub>rel</sub> = Relative C  
 C<sub>rel</sub>P = Relative CP  
 D = Determiner  
 DP = Determiner Phrase  
 D<sub>rel</sub> = relative determiner  
 EA = External Argument  
 ECM = Exceptional Case Marking  
 EF = Edge Feature  
 EM = External Merge  
 EPP = Extended Projection Principle  
 H = Head  
 HPSG = Head-Drive Phrase Structure Grammar  
 IM = Internal Merge  
 iPhi = interpretable phi-features (person, number, gender)  
 LA = Lexical Array  
 MG = Minimalist Grammar  
 MP = Minimalist Program  
 N = Noun  
 NP = Noun Phrase  
 Op = Operator  
**phi-features = person, number, and gender features**  
 POSS = possessive head 's  
 PP = Prepositional Phrase  
 pro = a pronoun that is not pronounced which is associated with Case positions.  
 PRO = a pronoun that is not pronounced which is associated with non-Case positions  
 pro<sub>n</sub> = a nominal pro  
 Q = Question  
 rel = relative feature  
 SO - Syntactic Object  
 T = Tense, a feature and a functional head  
 TP = Tense Phrase  
 T<sub>Past</sub> = Past Tense  
 uF = unvalued/uninterpretable feature  
 uPhi = unvalued/uninterpretable phi-features (person, number, gender)  
 uRel = unvalued Relative feature  
 iRel = interpretable Relative feature  
 uT = unvalued/uninterpretable T  
 v = Verb  
 V = Verb  
 v\* = transitive verbal head  
 VP = Verb Phrase  
 YP = a phrase with the head Y

## References

- Abney, Steven. 1987. *“The English noun phrase in its sentential aspect.”* PhD thesis. Cambridge, MA: Massachusetts Institute of Technology.
- Andor, Daniel, Chris Alberti, David Weiss, Aliaksei Severyn, Alessandro Presta, Kuzman Ganchev, Slav Petrov and Michael Collins. 2016. “Globally normalized transition-based neural networks.” In *Proceedings of the 54<sup>th</sup> Annual Meeting of the Association for Computational Linguistics*, 2442-2452. Berlin, Germany.
- Aoun, Joseph and Yen-hui Audrey Li. 2003. *Essays on the representations and derivational nature of grammar: The diversity of wh-constructions*. Cambridge, MA: MIT Press.
- Bauer, Laurie. 1994. *Watching English change: An introduction to the study of linguistic change in standard Englishes in the 20th century*. New York: Routledge.
- Bianchi, Valentina. 1999. *Consequences of antisymmetry: Headed relative clauses*. Berlin: Mouton de Gruyter.
- Bianchi, Valentina. 2000. The raising analysis of relative clauses: A reply to Borsley. *Linguistic Inquiry* 31, 123-140.
- Black, Alan W. “Formal properties of Feature Grammars.” Unpublished manuscript, 1986, typescript.
- Borsley, Robert D. 1997. “Relative clauses and the theory of phrase structure.” *Linguistic Inquiry* 28, 629-647.
- Brame, Michael. 1968. “A new analysis of relative clauses: Evidence for an interpretive theory.” Unpublished manuscript, 1968, typescript.
- Bruening, Benjamin, Xuyen, Dinh, & Lan Kim. 2018. “Selection, idioms, and the structure of nominal phrases with and without classifiers.” *Glossa: a journal of general linguistics* 3: 42. 1-46. doi: 10.5334/gjgl.288.
- Bruening, Benjamin. 2020. “The head of the nominal is N, not D: N-to-D movement, hybrid agreement, and conventionalized expressions.” *Glossa: a journal of general linguistics* 5: 15. 1-19. doi: 10.5334/gjgl.1031
- Carlson, Greg. 1977. “Amount relatives.” *Language* 53. 520-542. doi: 10.2307/413175.
- Cecchetto, Carlo & Caterina Donati. 2015. *(Re)labeling*. Cambridge, MA: MIT Press.
- Chomsky, Noam. 1977. “On wh movement.” In *Formal syntax*, edited by Peter W. Culicover, Thomas Wasow, and Adrain Akmajian, 71-132. New York: Academic Press.
- Chomsky, Noam. 1981. *Lectures on Government and binding: The Pisa Lectures*. Dordrecht: Foris.
- Chomsky, Noam. 1986. *Barriers*. Cambridge, MA: MIT Press.
- Chomsky, Noam. 1995. *The Minimalist Program*. Cambridge, MA: MIT Press.

- Chomsky, Noam. 2000. "Minimalist inquiries: The framework." In *Step by step*, edited by Martin, Roger, Michaels, David & Juan Uriagereka, 89-155. Cambridge, MA: MIT Press.
- Chomsky, Noam. 2001. "Derivation by phase." In *Ken Hale: A life in language*, edited by Michael Kenstowicz, 1-52. Cambridge, MA: MIT Press.
- Chomsky, Noam. 2004. "Beyond explanatory adequacy." In *Structures and beyond: The cartography of syntactic structures, Volume 3*, edited by Adriana Belletti, 104-132. Oxford, UK: Oxford University Press.
- Chomsky, Noam. 2008. "On phases." In *Foundational issues in linguistic theory; essays in honor of Jean-Roger Vergnaud*, edited by Robert Freidin, Carlos Otero, and Maria-Luisa Zubizarreta, 133-166. Cambridge, MA: MIT Press.
- Chomsky, Noam. 2011. "Language and other cognitive systems. What is special about language?" *Language Learning and Development* 7. 263-278. doi: 10.1080/15475441.2011.584041.
- Chomsky, Noam. 2013. "Problems of Projection." *Lingua* 130. 33-49. doi: 10.1016/j.lingua.2012.12.003.
- Chomsky, Noam. 2015. "Problems of projections: Extensions." In *Structures, strategies and beyond: Studies in honour of Adriana Belletti* edited by Di Domenico, Elisa, Cornelia Hamann and Simona Matteini, 1-16. Amsterdam: John Benjamins.
- Chomsky, Noam. 2021. "Minimalism: Where are we now, and where can we hope to go." *Gengo Kenkyu* 160. 1-41.
- Chomsky, Noam, and Howard Lasnik. 1995. The theory of principles and parameters. In *The Minimalist Program*, 13-127. Cambridge, MA: MIT Press.
- Citko, Barbara. 2001. "Deletion under identity in relative clauses." In *Proceedings of NELS 31*, 131-145. GLSA.
- Collins, Chris and Edward Stabler. 2016. "A formalization of Minimalist syntax." *Syntax* 19. 43-78. doi: 10.1111/synt.12117.
- Culicover, Peter W. 2013. *Grammar and complexity: Language at the intersection of computation and performance*. Oxford: Oxford University Press.
- Deal, Amy Rose. 2009. "The origin and content of expletives: Evidence from "selection"." *Syntax* 12. 285-323. doi: 10.1111/j.1467-9612.2009.00127.x.
- de Vries, Mark. 2002. "The syntax of relativization." PhD thesis. Amsterdam, Netherlands: University of Amsterdam.
- Epstein, Samuel David, Kitahara, Hisatsugu & T. Daniel Seely. 2014. "Labeling by Minimal Search: Implications for successive cyclic A-Movement and the conception of the

- postulate “phase”.” *Linguistic Inquiry* 45. 463-481. doi:  
<http://www.jstor.org/stable/43695654>.
- Fong, Sandiway, and Jason Ginsburg. 2012. “Computation with doubling constituents: Pronouns and antecedents in phase theory.” In *Towards a biolinguistics understanding of grammar: Essays on interfaces* edited by Anna Maria Di Sciullo, 303-338. Amsterdam: John Benjamins.
- Gallego, Angel. 2006. “T-to-C movement in relative clauses.” In *Romance languages and linguistic theory 2004: Selected papers from 'Going Romance', Leiden, 9-11 December 2004*, edited by Jenny Doetjes and Paz Gonzalez, 143-170. Amsterdam: John Benjamins.
- Hale, John T. 2001. “A probabilistic Early parser as a psycholinguistic model.” In *Proceedings of the 2nd Meeting of the North American Chapter of the Association for Computational Linguistics on Language Technologies*, 1-8. Association for Computational Linguistics. doi: 10.3115/1073336.1073357.
- Hale, John T. 2003. “Grammar, uncertainty and sentence processing.” PhD thesis. Baltimore, MD: The Johns Hopkins University.
- Hankamer, Jorge. 1973. “Why there are two *than*’s in English.” In *Papers from the 9<sup>th</sup> regional meeting of the Chicago Linguistics Society* edited by C. Corum, T.C. Smith-Stark, and A. Weister, 179-191. Chicago: Chicago Linguistics Society.
- Harkema, Hendrik. 2001. “Parsing minimalist languages.” PhD thesis. Los Angeles, CA: University of California, Los Angeles.
- Haumann, Dagmar. 2007. *Adverb licensing and clause structure in English*. Amsterdam: John Benjamins.
- Henry, Alison. 1995. *Belfast English and standard English*. Oxford: Oxford University Press.
- Higgins, George V. 1976. *The judgement of Deke Hunter*. London: Secker and Warburg.
- Indurkya, Sagar. 2021. “Solving for syntax.” PhD thesis. Cambridge, MA: The Massachusetts Institute of Technology.
- Johnson, Mark. 1988. *Attribute-value logic and the theory of grammar*. Stanford, CA: CSLI Lecture Notes.
- Kayne, Richard. 1994. *The antisymmetry of syntax*. Cambridge, MA: MIT Press.
- Keenan, Edward L., and Sarah Hawkins. 1987. The psychological validity of the Accessibility Hierarchy.” In *Universal Grammar: 15 Essays* edited by Edward L. Keenan, 60-85. London. Croom Helm.
- Kroch, Anthony, and Ann Taylor. 2000. *Penn-Helsinki parsed corpus of Middle English Second Edition*. <http://www.ling.upenn.edu/histcorpora/PPCME2-RELEASE-3/>

- Labov, William. 1972. *Language in the inner city: Studies in the Black English Vernacular*. Philadelphia: University of Pennsylvania Press.
- Larson, Richard K. 1985. Bare-NP adverbs. *Linguistic Inquiry* 16, 595-621.
- Marantz, Alec. 1997. "No escape from syntax: Don't try morphological analysis in the privacy of your own lexicon." In *University of Pennsylvania Working Papers in Linguistics* 4(2), 201-225.
- Müller, Gereon. 2011. *Constraints on displacement: A phase-based approach*. Amsterdam: John Benjamins.
- Müller, Stefan. 2015. "The CoreGram project: theoretical linguistics, theory development, and verification." *Journal of Language Modeling* 3, 21-86.
- Nivre, J, 2003. "An efficient algorithm for projective dependency parsing." In *Proceedings of the 8<sup>th</sup> International Conference on Parsing Technology*, 149-160. Nancy, France.
- Pesetsky, David & Esther Torrego. 2001. "T-to-C movement: Causes and consequences." In *Ken Hale: A life in language*, Michael Kenstowicz (ed.), 355-426. Cambridge, MA: MIT Press.
- Pesetsky, David & Esther Torrego. 2007. The syntax of valuation and the interpretability of features. In *Phrasal and clausal architecture: Syntactic derivation and interpretation. In honor of Josephy E. Emonds*, edited by Simin Karimi, Vida Samiian, and Wendy Wilkins, 262-294. Amsterdam: John Benjamins.
- Radford, Andrew. 1997. *Syntax: A minimalist introduction*. Cambridge, UK: Cambridge University Press.
- Radford, Andrew. 2016. *Analysing English sentences, second edition*. Cambridge, UK: Cambridge University Press.
- Radford, Andrew. 2019. *Relative clauses: Structure and variation in everyday English*. Cambridge, UK: Cambridge University Press.
- Ringe, Don and Ann Taylor. 2014. *The development of Old English: A linguistic history of English, volume II*. Oxford: Oxford University Press.
- Sag, Ivan A. 1997. "English relative clause constructions." *Journal of Linguistics* 33. 431-483. doi: <https://www.jstor.org/stable/4176423>
- Salzmann, Martin. 2017. *Reconstruction and resumption in indirect A'-dependencies: On the prolepsis and relativization in (Swiss) German and beyond*. Berlin: Walter de Gruyter.
- Santorini, Beatrice, and Anthony Kroch. 2007. "The syntax of natural language: An online introduction using the Trees program." Unpublished manuscript, 2007. Retrieved from <http://www.ling.upenn.edu/~beatrice/syntax-textbook>

- Schachter, Paul. 1973. "Focus and relativization." *Language* 49. 19-46.
- Shannon, Dell. 1978. *Cold trail*. London: Gollancz.
- Sistrunk, Walter. 2012. *The syntax of zero in African American relative clauses*. PhD thesis. East Lansing, MI: Michigan State University.
- Sobin, Nicholas. 2014. "Th/Ex, agreement, and case in expletive sentences." *Syntax* 17. 385-416.
- Stabler, Edward P. 1997. "Derivational Minimalism." In *Logical Aspects of Computational Linguistics, Lecture Notes in Computer Science 1328*, edited by Christian Retoré, 68-95. Berlin: Springer-Verlag.
- Stabler, Edward P. 2011. "Computational perspectives on Minimalism." In *Oxford Handbook of Linguistic Minimalism*, edited by Cedric Boeckx, 617-643. Oxford, UK: Oxford University Press.
- Torr, John, Stanojević, Milos, Steedman, Mark and Shay B. Cohen. 2019. "Wide-coverage Neural A\* parsing for Minimalist Grammars." In *Proceedings of the 57<sup>th</sup> Annual Meeting of the Association for Computational Linguistics*, 2486-2505.
- van Gelderen, Elly. 2013. *Clause Structure*. Cambridge: Cambridge University Press.
- van Gelderen, Elly. 2014. *A history of the English language, revised edition*. Amsterdam: John Benjamins.
- Vergnaud, Jean-Roger. 1974. *French relative clauses*. PhD thesis. Cambridge, MA: Massachusetts Institute of Technology.
- Wolfe, Gene. 1977. "The eyeflash miracles." In *Best Science Fiction of the Year 6*, edited by Terry Carr. London: Gollancz.