Chapter 12

Unbounded dependencies

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Grammatical representations and the operations defined on them are designed to take advantage of the fact that most syntactic dependencies (such as agreement, government, and control) are local. Typically they can be defined on string-adjacent elements or on elements that can be made tree-adjacent with hierarchical structures of modest and definite depth. It is also well known, however, that languages exhibit some phenomena that require the capability to describe syntactic relations that hold over wider domains. With such unbounded dependencies a grammatical function assigned within an embedded clause is correlated with a configuration of items that appear elsewhere in the sentence and perhaps far away from the other words and phrases that make up that clause. This is a characteristic pattern in particular of topicalization, constituent questions, relative clauses, and *tough*-adjective constructions.

The earliest LFG approaches to unbounded dependencies were modeled after the phrase structure solutions of other frameworks, but it is now generally recognized that the functional configurations enshrined in f-structure support the simplest descriptions and explanations. This chapter surveys many of the theoretical and empirical issues that have been discussed in the LFG literature and in the linguistic literature more broadly. Unbounded dependencies interact in complicated ways with the syntactic properties that define the local organization of clauses and sentences. Within LFG, functional uncertainty combines with off-path annotations to offer the most natural and direct accounts of these complex interactions. These technical devices integrate well with other aspects of the LFG formalism.

Grammatical representations and the operations defined on them are designed to take advantage of the fact that most syntactic dependencies (such as agreement, government, and control) are local. Typically, they can be defined on string-adjacent elements or on elements that can be made tree-adjacent with hierarchical structures of modest and definite depth. It is also well known, however, that

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languages exhibit some phenomena that require the capability to describe syntactic relations that hold over wider domains. With such unbounded dependencies, a grammatical function assigned within an embedded clause is correlated with a configuration of items that appear elsewhere in the sentence and perhaps far away from the other words and phrases that make up that clause. Constructions with different patterns of unbounded dependencies have posed descriptive and explanatory challenges to most grammatical theories. This is because the correlations can be sensitive in intricate ways not only to internal properties of the clause and properties of the external configuration, but also to syntactic properties of the intervening material.

There is a substantial literature that aims to identify principles that apply broadly, if not universally, to condition the appearance of unbounded dependencies and also to identify the dimensions of variability across constructions and languages. This chapter surveys just some of the major descriptive and theoretical challenges that these dependencies have presented and sketches how they have been, or in some cases might be, addressed with the tools and techniques of Lexical Functional Grammar. Section 1 sets the stage for this discussion with some simple examples of the topicalization construction. These show that a phrase at the front of a sentence is interpreted as an argument of a distant predicate and its syntactic features are governed by that predicate. Kaplan & Bresnan (1982) proposed an LFG account of unbounded dependencies based on the categories and dominance relations of c-structure. Section 2 outlines that original proposal but then summarizes the considerations that led Kaplan & Zaenen (1989) to conclude that these dependencies are better described in functional terms, as instances of "functional uncertainty". Functional uncertainty is a straightforward extension to the notation of functional descriptions and has now become the standard mechanism for characterizing unbounded dependencies in LFG grammars.

English constituent questions (Section 3) are slightly more complicated than topicalizations because of the additional requirement that an interrogative pronoun exists at an uncertain position inside the initial question phrase. In traditional treatments the topicalized and question phrases correspond to the values of distinguished f-structure attributes, TOPIC and FOCUS respectively, that serve as signals for the discourse entailments of these constructions. It has been argued that those entailments properly belong to a separate component of grammar, Information Structure (Zaenen forthcoming [this volume]), and this suggests (Section 4) removing such grammaticized discourse functions from f-structure in favor of explicit mappings to i-structure made possible by LFG's Correspondence Architecture.

The English *tough* construction (Section 5) is of interest because its unbounded dependency is introduced by an annotation in a lexical entry rather than a c-structure rule, and also because the shared f-structure element is governed by predicates in two different clauses. This may lead to a connectivity problem wherein a sentence is grammatical even though the two clauses assign incompatible values to some features, CASE in particular. This section outlines several solutions to that problem. Connectivity is also a potential issue for relative clauses, since as in *tough* constructions the relativized NP appears to play a role in two clauses. Relative clauses have the additional complexity, like constituent questions, that an initial topic phrase must contain a relative pronoun at some uncertain position. Relative clauses are discussed in Section 6.

Section 7 covers a collection of constraints that may be layered on top of the basic constructions previously described. For some constructions in some languages the form of a clause may change if a dependency passes through it. Some clauses and some configurations are impervious to unbounded dependencies, forming what are traditionally known as islands. And there are also linear order constraints that seem to tie the functionally-specified unbounded dependencies more closely to the sequence of words in the sentence. The last section discusses possible LFG accounts for parasitic gaps and other multiple gap constructions, a dependency pattern that is unexpected and problematic for almost every grammatical theory.

1 Topicalization: A simple unbounded dependency

Typical examples of unbounded dependencies are topicalization, constituent questions, and relative clauses in English and other languages. What is important in these constructions is that an element in a matrix clause bears a grammatical function governed by the verb in a clause that may be arbitrarily far away in the sentence. This is exemplified by the topicalization in (1).

(1) Mary, John claimed that Bill said that Henry called.

In (1), *Mary* is understood as the object of *called* but it occurs outside the embedded clause that contains that verbal predicate. Hence local functional equations are not able to describe the dependency nor can it be inferred from the local c-structure hierarchy. Without further specification the embedded f-structure will be incomplete. Of course the grammar can include a local functional dependency with a long sequence of attributes to share information between the higher and lower clauses in this particular sentence. But the hallmark of dependencies of this type is that they tend to be unbounded in the sense that the embedding structure can be arbitrarily deep, as the following variant of (1) suggests:

(2) Mary, John claimed that Bill said that Henry expected to call.

There is little morphological marking on the elements of English topicalization. But in other languages it is very clear that the external item must have the markings that go along with the clause-internal grammatical function to which it is assigned. The following German example is an illustration of such a correlation:

(3) German (Berman 2003)
Den Peter glaube ich hat die Maria eingeladen
the.ACC Peter believe I has the Maria invited
'Peter, I think that Maria has invited.'

Here *den Peter* is in the accusative because *einladen* 'invite' takes an accusative object. Case marking is not the only connectivity effect. Reflexivization constraints also register the external element as fulfilling a function in the embedded f-structure, as shown in the following Icelandic example:

(4) Icelandic
Sjálfum sér held ég ekki að Jón geðjist.
Himself think I not that John likes.
'I don't think that John likes himself.'

In Icelandic, elements that are coreferent with the subject of their clause need to take a reflexive form (*sjálfum* in this example) that is distinct from a nonreflexive pronoun (*hann*). This requirement must be satisfied even when the subject is realized outside of the clause.

As a first approximation, the obvious way to handle such interactions is through the kind of structure sharing that is used in LFG descriptions of raising constructions (Vincent forthcoming [this volume]). There it is also the case that an f-structure element plays two roles, e.g. subject of a lower clause and object of a higher one. What is different in the case of unbounded dependencies is the fact that the inventory of possible f-structure paths between higher and lower elements cannot in principle be characterized by finite sequences of intermediate functions.

2 LFG formalizations

LFG has two types of syntactic representations and it is not clear *a priori* whether unbounded dependencies should be modeled in the c-structure or in the f-structure.

2.1 Early approach based on c-structure

In Kaplan & Bresnan (1982) unbounded dependencies were modeled via the c-structure spine as in many other frameworks of that period. The representation for sentence (1) is shown in Figure 1.[1]

In this formulation the linkage between the clause-external item and its clause-internal function is specified by the c-structure rules in (5). This analysis depends on the fact that the OBJ function is assigned to an NP under VP (5c) and that any NP can expand to an empty "trace" node, indicated by e in (5b).

(5) a. CP $\longrightarrow$ NP C′
$(\uparrow \text{TOPIC}) = \downarrow$ $\uparrow=\downarrow$
$\downarrow = \Downarrow$

b. NP $\longrightarrow$ e
$\uparrow = \Uparrow$

c. VP $\longrightarrow$ V NP
$\uparrow=\downarrow$ $(\uparrow \text{OBJ})=\downarrow$

The double arrows ⇑ and ⇓ are metavariables, like ↑ and ↓, that denote the f-structures corresponding to c-structure nodes in particular configurations. In the annotations on a daughter category in a given rule, ↑ refers to the f-structure corresponding to the mother node, and ↓ refers to the f-structure corresponding to the daughter. In contrast, the double arrows (called "bounded-domination metavariables") match nodes that are separated in the c-structure but are related

[1]The nodes in this c-structure are labeled with modern X′ categories instead of the traditional categories found in earlier LFG papers (e.g. Kaplan & Bresnan 1982; Kaplan & Zaenen 1989). But I depart from common X′ assumptions in showing c-structures that are not cluttered with nodes that are nonbranching, nonmajor, nonlexical, and functionally transparent (annotated with ↑=↓). Other categories (like C′ and VP′) can appear as macro arguments, phantom categories, or metacategories in c-structure grammar specifications (Kaplan & Maxwell 1996; Crouch et al. 2011) and thus can still be used to express generalizations over the context-free rules that describe well-formed c-structures. In that regard they have the same explanatory value as the names and arguments of the f-structure templates discussed by Dalrymple et al. (2004). These reduced c-structures are compatible with Bresnan's (2001) notion of economy and with Lovestrand & Lowe's (2017) theory of minimal phrase structure.

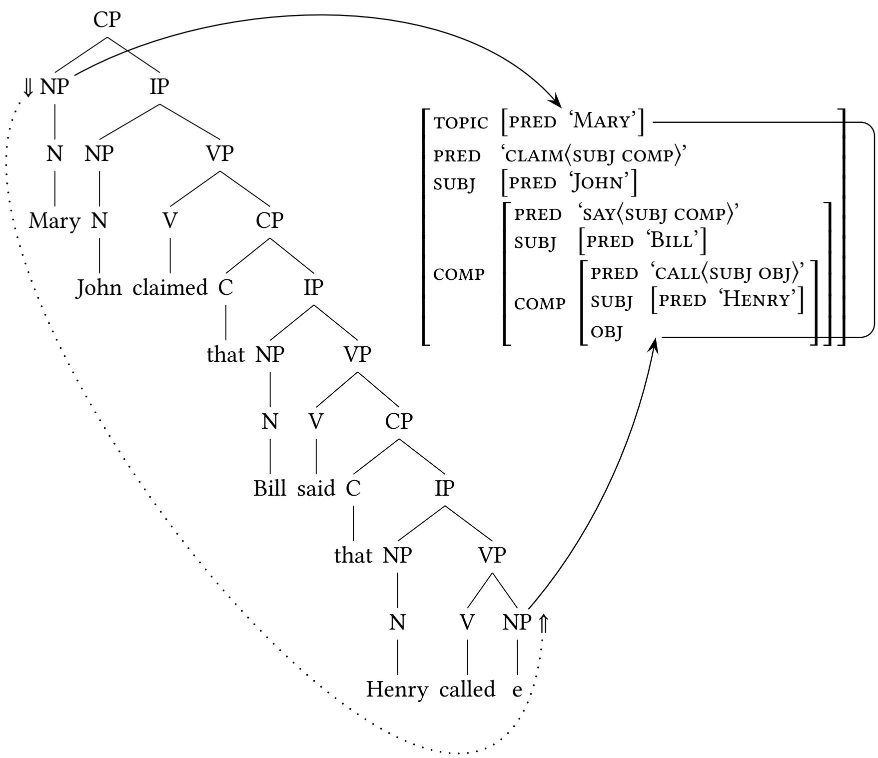


Figure 1: Long-distance relation in c-structure induces f-structure sharing for sentence (1), following Kaplan & Bresnan (1982).

through a longer dominance path. Thus the NP in front is a sister of a clause that contains the trace node, and the dominance path between the nodes is allowed because it does not contain other nodes that encode so-called island constraints (see Section 7.2). The dotted line in Figure 1 connects the two c-structure nodes with matching double arrows. The c-structure-to-f-structure correspondence then induces the sharing relationship depicted in the f-structure. The TOPIC function records the special significance of the external constituent as a placeholder for subsequent interpretation by other components of grammar, but it is not here involved in establishing the syntactic connection; Section 4 revisits the grammatical status of the discourse attributes TOPIC and FOCUS.

In this example the nodes that are linked by the double-arrows are both labeled by the same c-structure category NP, but this is not a necessary property of the topicalization construction. Indeed, Kaplan & Bresnan (1982) noted that in some cases instead the nodes are required to have categories that mismatch, as illustrated in (6). Examples (6a-b) show that a CP complement can appear within a clause immediately after *think* but not after *think of*. In contrast, a CP complement in topicalized position is acceptable only when it is linked to the canonical NP position after *of* (6c-d).

(6) a. He didn't think that he might be wrong.
b. * He didn't think of that he might be wrong.
c. * That he might be wrong he didn't think.
d. That he might be wrong he didn't think of.

In the face of examples such as these, Kaplan & Bresnan (1982) embellished their node-linking notation to enable a more intricate relationships of nodes and categories.

It became apparent through subsequent research, however, that constraints on unbounded dependencies are generally more sensitive to functional rather than to c-structure properties. Kaplan & Zaenen (1989) point out that in Icelandic, for example, binding into COMPs is possible but binding into adjunct clauses is restricted, even when these two types of embeddings have similar c-structures. They consider the following sentences:

(7) Icelandic
a. Jón var að þvo gólfið eftir að María hafði skrifað bréfið.
John was at wash floor.the after that Maria had written letter.the
'John was washing the floor after Maria had written the letter.'

b. þu vonaðist til að hann fengi bíl.
You hoped for that he will.get car
'You hoped that he would get a car.'

They argue that both embedded clauses are introduced with a PP that is the c-structure sister of the main verb, but the f-structures for these sentences are different. In the first example the embedded clause is not an argument of the main verb whereas in the second one it is. This difference correlates with the binding contrast illustrated in (8).

(8) Icelandic
a. *Þessi bréf var Jón að þvo gólfið eftir að María hafði skrifað.
this letter was John at wash floor.the after that Maria had written
'This letter, John was washing the floor after Maria had written.'

b. Hvaða bíl vonaðist þú til að hann fengi.
Which car hoped you for that he will.get
'Which car did you hope that he would get?'

These Icelandic contrasts and the English examples (6) together suggest that the constraints on unbounded dependencies cannot easily be stated in terms of c-structure categories and configurations. In both cases a more natural account can be formulated in terms of functional properties, the difference between arguments and adjuncts, in the Icelandic case, and the restriction against the COMP function with the predicate *think* in the English case.

In general, unbounded dependencies are acceptable only if they assign clause internal functions that satisfy the subcategorization requirements of the embedded predicates. The topicalization example (1) is grammatical because the predicate *call* subcategorizes for the function OBJ; the putative topicalization (9c) is ungrammatical because *arrive* is intransitive.

(9) a. I think Henry will call Mary.
b. * I think Henry will arrive Mary.
c. * Mary I think Henry will arrive.

The fact that subcategorization in LFG is defined at the level of f-structure via the Completeness and Coherence Conditions provided strong motivation for investigating a functional approach to unbounded dependencies.

Additional motivation comes from the fact that unbounded dependencies resemble more local dependencies in the way that they interact with coordinate structures. Sentence (10a) is grammatical because *dedicate* subcategorizes for both an OBJ and an oblique function OBL_θ while (10b) is unacceptable because *bake* does not subcategorize for OBL_θ. Grammatical functions in LFG distribute to all of the conjuncts of a coordination set (Bresnan et al. 1985; Kaplan & Maxwell 1988b; Dalrymple & Kaplan 2000, Patejuk forthcoming [this volume]), and thus the coordination (10c) fails Coherence just as in the uncoordinated case. The topicalization (10d) is also ungrammatical, and the simplest explanation is that the within-clause function of the external phrase is distributed in the ordinary way across both predicates.

(10) a. John dedicated a pie to Bill.
b. * John baked a pie to Bill.
c. * John dedicated and baked a pie to Bill.
d. * To Bill, John dedicated and baked a pie.

2.2 Uncertainty of function assignments

Based on these considerations, Kaplan & Zaenen (1989) developed an approach that refers mainly to f-structure notions to characterize the nature of unbounded dependencies. The f-structure sharing induced by the domination metavariables for the particular example in Figure 1 can be specified directly by the f-description annotation in the alternative rule (11a). This is true even if a c-structure rule such as (5b) is not used to provide a trace NP. Instead, a traceless c-structure configuration is licensed by the alternative VP rule (11b), independently needed for the analysis of clauses with intransitive verbs.

(11) a. $\text{CP} \longrightarrow \underset{\substack{(\uparrow \textsc{topic}) = \downarrow \\ (\uparrow \textsc{comp comp obj}) = \downarrow}}{\text{NP}} \quad \underset{\uparrow = \downarrow}{\text{C}'}$

b. $\text{VP} \longrightarrow \underset{\uparrow = \downarrow}{\text{V}}$

The grammatical functions on the longer path in (11a) match the blue attributes in the f-structure in Figure 2 and thus establish the intended link for sentence (1).

For the dependency in sentence (2), however, a longer equation with an additional XCOMP is required, and it is not clear at the position of the topic NP which of the two equations should be chosen to fit the f-structure embeddings of the following clause. In fact, since there is no bound in principle on the depth of an unbounded dependency, there would be infinitely many equations to choose from to account for all possible linkages to the within-clause function of the external NP.

Kaplan & Zaenen (1989) addressed the unbounded uncertainty of the within-clause function assignment by extending the notation and interpretation of LFG's functional descriptions. Kaplan & Bresnan (1982) introduced the basic format and satisfaction condition for function-application expressions of single attributes in (12a) and for notational convenience provided the left-associative extension to a path of attributes in (12b), with (12c) defining the base case of an empty string. Condition (12d) is satisfied by members of a set of f-structure elements, and the later addition (12e) is the foundation for LFG's distributive theory of coordination, as illustrated in (10) above.

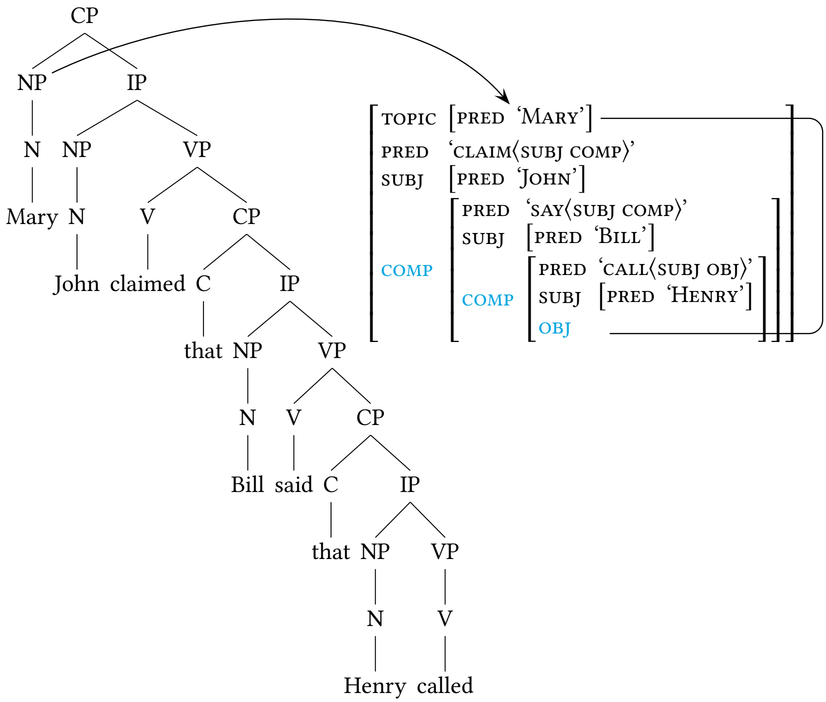


Figure 2: Unbounded relation for sentence (1) defined directly in f-structure via the path of blue attributes (after Kaplan & Zaenen 1989).

(12) Satisfaction conditions for attributes

a. $(f\ a) = v$ iff f is an f-structure, a is an attribute and $\langle a, v\rangle \in f$.

b. $(f\ a\sigma) = v$ iff $a\sigma$ is a string of attributes and $((f\ a)\ \sigma) = v$.

c. $(f\ e) = v$ iff $f = v$ (e denotes the empty string).

Satisfaction conditions for sets

d. $v \in f$ iff f is a set and v belongs to f.

e. $(f\ a) = v$ iff f is a set and

$(g\ a) = v$ for all $g \in f$	if a is a distributive attribute
$\langle a, v\rangle \in f$	if a is a nondistributive attribute.

Kaplan & Zaenen (1989) first generalized from the single-string specification (12b) to sets of attribute strings as in (13a).

(13) Functional uncertainty

a. If PATHS is a set of attribute strings,
$(f\ \text{PATHS}) = v$ iff $((f\ a)\ \mathit{Suff}(a, \text{PATHS})) = v$, where
$\mathit{Suff}(a, \text{PATHS}) = \{\sigma \mid a\sigma \in \text{PATHS}\}$.
(the suffixes of strings in PATHS that begin with attribute a)

b. $(f \in) = v$ iff $v \in f$ for the special "attribute" $\in$.

The uncertainty about which paths might result in complete and coherent within-clause function assignments is represented under this formulation by the choice between alternative strings in such a path language. A language containing at least the strings COMP COMP OBJ and COMP COMP XCOMP OBJ, for example, would account for both topicalization sentences (1–2). According to (13b), if the special attribute $\in$ on a path coincides with a set of f-structures, the path can continue through any one of the set's freely chosen elements.

A finite enumeration of path-strings is in essence only a succinct way of specifying a finite disjunction; it would not yet express the unbounded nature of these dependencies. But Kaplan & Zaenen (1989) went further and allowed path-sets to be regular languages containing possibly an infinite number of strings. Such languages can be specified as regular expressions that appear in the annotations in rules and lexical entries. Rule (14) extends the particular annotation in rule (11) to account not only for examples (1–2) but also for topicalizations with COMP embeddings of arbitrary depth.

(14)
$$\text{CP} \longrightarrow \begin{array}{c}\text{NP}\\ (\uparrow \text{TOPIC}) = \downarrow\\ (\uparrow \text{COMP}^{*}\ \text{OBJ}) = \downarrow\end{array} \quad \begin{array}{c}\text{C}'\\ \uparrow = \downarrow\\ \ \end{array}$$

Each of the infinitely many paths in this uncertainty language begins with some number of COMPs, what Kaplan and Zaenen called the "body", and finally ends in OBJ (the "bottom"). Rule (15) covers a larger set of English topicalization patterns by relaxing the category of the external phrase and enlarging the set of paths in the uncertainty language.[2]

[2] In movement-based frameworks the clause-external c-structure phrase in topicalization and other constructions is often referred to as the "filler" of the dependency and the string position of a putative trace node is known as the "gap". That conventional terminology translates to the LFG functional account with the proviso that the filler refers not to the external phrase but to its corresponding f-structure, and the gap is the within-clause function assignment of that f-structure. The canonical string position for the gap function (or the position of the empty node in a trace-based analysis) is often marked by an underscore, just as a reader's guide to the intended interpretation.

(15) CP ⟶ XP C′
(↑ TOPIC) = ↓ ↑=↓
(↑ TopicPaths) = ↓
where TopicPaths is {COMP, XCOMP, ADJ (∈)}* [GF−COMP]

As discussed by Kaplan and Zaenen, CP is a possible realization for the generic XP category in this rule and thus provides the c-structures for the topicalized complements of *think* in (6c–6d). The relative-difference [GF−COMP] at the bottom of every uncertainty path disallows COMP but includes OBJ, SUBJ, OBL_θ, ADJ, and every other function. The short, bottom-only path-string COMP is thus not available for the inadmissible example (6c). Adding XCOMP to the body of this expression allows for the bottom function to be embedded under a mixture of tensed and infinitival complements. Given (13b), the ADJ and ∈ options provide an analysis for the English sentences (16) (examples from Dalrymple 2001); presumably ADJ would not appear in the language of Icelandic paths.

(16) a. Julius teaches his class in this room.
b. This room Julius teaches his class in.
c. In this room Julius teaches his class.

Further extensions and restrictions on the TopicPaths and other path language are discussed in later sections.

Functional uncertainty has become the primary technical device for describing unbounded dependencies in LFG. Uncertainty languages can be defined by the primitive regular-expression operators of concatenation, union (curly braces), optionality (parentheses), and Kleene-star and Kleene-plus repetition. Indeed, since the regular languages are closed under intersection and complementation, a collection of attribute paths can be specified by any Boolean combination of the same regular predicates that are allowed in the right sides of LFG c-structure rules (see Kaplan & Maxwell 1996; Crouch et al. 2011). This includes the relative difference operator [GF−COMP] above and its equivalent but more succinct term-complement predicate \COMP. Path languages that describe a wide range of constructions in different languages can thus be expressed as the composition of separate, simpler formulas that encode independent linguistic generalizations, as illustrated in later sections. Also of importance, it has been shown that the satisfiability of functional descriptions remains decidable when the LFG formalism is extended with regular path languages (e.g. Kaplan & Maxwell 1988a; Backofen 1993).

3 Constituent questions

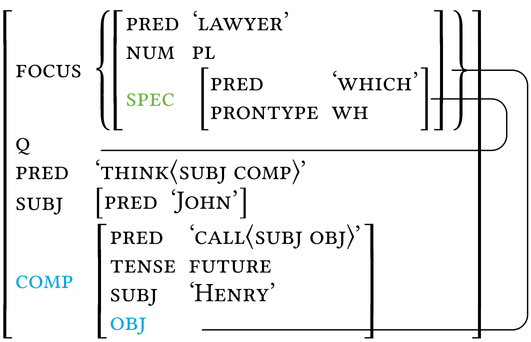
Constituent questions in English resemble topicalization in that the f-structure of a clause-external phrase is assigned a grammatical function at some level inside its sister clause. The possibilities for the dependency path between the filler and its within-clause function are similar, but there is an additional requirement that the filler either must be an interrogative (*wh*) pronoun or must contain one. The examples of indirect questions in (17) illustrate some of the possibilities.

(17) I wonder ...

a. who John thinks Henry will call.
b. which lawyer John thinks Henry will call.
c. whose friend John thinks Henry will call.
d. whose lawyer's friend John thinks Henry will call.
e. from whom John thinks Mary will get a call.
f. when John will call Mary.
g. * this lawyer John thinks Henry will call.
h. * he John thinks Henry will call.

Kaplan & Bresnan (1982) proposed the attribute FOCUS (distinct from the topicalization attribute TOPIC) as a placeholder for the communicative entailments of the question construction, and a separate attribute Q to place the interrogative pronoun in a canonical position for later interpretation. An f-structure configuration with these attributes for the embedded question in (17b) is shown in (18).

(18)



FOCUS is represented here as taking a set of f-structures as its value. It can thus hold the contributions of additional English question words that might appear in situ (19a) or the multiple question words in initial position that other languages might allow (19b).

(19) a. I wonder who John thinks would like to get what.

b. Hungarian (from Mycock 2007)

Ki	ki-t	ki-nek	mutat-ott	be?
who-NOM	who-ACC	who-DAT	introduce-PAST-DEF.3SG	VM

'Who introduced who to who?'

The f-structure (18) for the embedded question (17b) is assigned by rule (20). The FocusPaths uncertainty resolves to the blue attribute sequence that relates the entire filler f-structure to its within-clause (non-COMP) function, as for topicalization. The green path, taken from WhPaths, establishes Q as an element inside the filler. The intersection with WhPro further ensures that Q is an interrogative pronoun: given the off-path $=_c$ constraint, the f-structure at the end of any WhPaths string is acceptable only if it also includes the feature [PRONTYPE WH]. Off-path annotations are discussed in Section 7.1 and defined there in (55).

(20) CP ⟶ XP IP

XP: ↓ ∈ (↑ FOCUS)
(↑ FocusPaths) = ↓
(↑ Q) = (↓ WhPaths & WhPro)

IP: ↑=↓

where FocusPaths is {COMP, XCOMP, ADJ (∈)}* \COMP
WhPaths is {SPEC*,OBJ}
WhPro is GF* GF
(→ PRONTYPE) $=_c$ WH

In fuller treatments, of course, the uncertainty languages FocusPaths and WhPaths are supplemented with appropriate configurations of obliques, adjuncts, and other grammatical functions.

The initial phrase of the English c-structure configuration is the probable cause, the trigger, for introducing the FocusPaths uncertainty expression, and this must then resolve to the proper within-clause grammatical function for that FOCUS phrase. In Mandarin interrogative pronouns appear in situ, at the position in the embedded clause where the proper function is assigned by normal clause-level rules. Huang (1993) discusses the following example.

(21) Mandarin

Zhangsan	xiwang	Lisi	gen	shei	xue	yuyanxue?
Zhangsan	hope	Lisi	GEN(with)	who	learn	linguistics

'With whom does Zhangsan hope that Lisi will learn linguistics?'

An unbounded uncertainty is not needed here to establish the within-clause function, and indeed there is no natural place in the c-structure to specify a

FocusPaths connection as in (20). But Huang notes that the pronoun must still be linked to some enclosing f-structure in order to establish the necessary scope for semantic and discourse interpretation. He proposes to include in the lexical entry of an interrogative pronoun an uncertain path language that resolves to a higher-level f-structure. Along the lines of that proposal, the lexical entry (22) places the interrogative pronoun in the focus set of a clause from which it is accessible through a path in the collection of (Mandarin-specific) FocusPaths.

(22) *shei*: $\uparrow \in$ ((FocusPaths $\uparrow$) focus)

This makes use of the formal device of *inside-out function application* (23a), originally introduced by Kaplan (1988) and subsequently extended by Halvorsen & Kaplan (1988) to uncertain path languages (23b).

(23) Inside-out function application

  a. $(\sigma\, f) = g$ iff σ is an attribute string and $(g\, \sigma) = f$.

  b. (Paths f) $= g$ iff Paths is a set of attribute strings and (g Paths) = f.

In this case also there is an explicit probable cause for the uncertainty, the interrogative lexical entry. In contrast, there is typically no local evidence to trigger the inside-out uncertainties that are attached to empty nodes in trace-based theories of unbounded dependencies (e.g. Bresnan 2001; Bresnan et al. 2016).

4 Grammaticized discourse functions?

Kaplan & Bresnan (1982) introduced the attributes topic and focus to distinguish the fillers of the different unbounded dependency constructions as separate from the establishment of their within-clause grammatical functions. These f-structure attributes were presumed to represent the syntactic features needed for subsequent interpretation by semantic and discourse components of grammar, and they were maintained as "grammaticized discourse functions" in some later work (e.g. Bresnan & Mchombo 1987). Other chapters describe the subsequent development of explicit theories of semantic representation (Asudeh forthcoming [this volume]) and information structure (Zaenen forthcoming [this volume]) and how LFG's Correspondence Architecture (Kaplan 1987, 1995) provides a uniform framework for integrating such independent modules with the core components of syntax. The literature surveyed in those chapters and also Dalrymple et al. (2019) suggest that the entailments of discourse functions like topic and focus can be spelled out in information structure (i-structure) features such as ±NEW and ±PROM(inent) and by other potential i-structure concepts that help in managing how semantic content is transmitted from speaker to hearer.

With respect to the external phrases of topicalization and question formation, if their different discourse entailments can be carried over to i-structure, there may no longer be motivation to mark those with the distinguished TOPIC and FOCUS attributes in f-structure. Thus, to record the external element in either construction, Asudeh (2004, 2012) proposed just one "overlay function" UDF (for "Unbounded Dependency Function"), Alsina (2008) suggested the attribute OP (for "operator"), and Dalrymple et al. (2019) used the attribute DIS (for "dislocated"). Snijders (2015) goes even further, questioning whether the filler f-structure of either construction is needed other than at its within-clause position. This issue was foreshadowed in King's (1997) earlier and more general argument that discourse focus should be represented in the independent information-structure module. If the discourse functions do not interact with other syntactic features and if the i-structure discourse status of the within-clause function can be signaled without them, then the f-structure clutter of these grammaticized functions can be eliminated entirely. In the following, I explore this possibility.

The Correspondence Architecture is designed to encourage theoretical modularity, allowing different components of linguistic description to be organized in their own most natural ways and avoiding the complexity and confusion that comes from mixing conceptually unrelated primitives in a single representation. Dalrymple & Nikolaeva (2011) propose to relate f-structure to i-structure with the correspondence functions diagrammed in (24) (see also Dalrymple et al. 2019). The projection σ maps from units of f-structure to meaning constructors in semantic structure, and the projection ι maps meaning constructors into correlated properties in information structure.

(24) I-structure correspondences (from Dalrymple & Nikolaeva 2011)

$$\text{c-structure} \xrightarrow{\phi} \text{f-structure} \xrightarrow{\sigma} \text{s-structure} \xrightarrow{\iota} \text{i-structure}$$

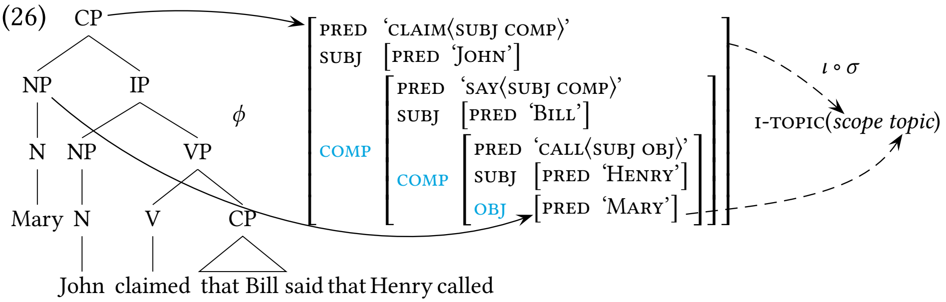
Given this arrangement and without involving any special features in f-structure, the composition of projections $\iota \circ \sigma \circ \phi$ can be used to express the fact that the filler in the topicalization construction is interpreted as an i-structure topic.

The abstract interface between the syntactic and information modules, according to this organization, is made explicit in the revision of the topicalization rule (15) shown in (25a). The TOPIC function assignment has been replaced by the invocation of the TOPIC template defined in (25b) (for more on the explanatory value of templates, see the discussion in Dalrymple et al. 2004).

(25) a. CP ⟶ XP C′
@(TOPIC ↑ ↓) ↑=↓
(↑ TopicPaths) = ↓

b. TOPIC(*scope topic*) ≡ @(I-TOPIC $scope_{\sigma\iota}$ $topic_{\sigma\iota}$)

The template I-TOPIC is a placeholder for a separate i-structure theory of topic whose details are hidden from the syntactic modules, but substituting the f-structure designators ↑ and ↓ for the template parameters *scope* and *topic* makes clear that the information needed to interpret the topic is carried by the external phrase.[3] The subscript $\sigma\iota$ is the conventional way of notating the composition of projections in LFG annotations. In comparison to the structures shown in Figure 2 for sentence (1), this gives rise to the three-module relationships in (26).

(26)


Note that there is no TOPIC and no structure sharing in this f-structure. The filler f-structure appears only at the position of its within-clause function, with the projection lines indicating how the c-structure phrases relate indirectly through the f-structure to the topic in i-structure.

Rule (27a) is a similar revision of the constituent question rule (20). The three-place template FocusQ defined in (27b) makes properties of the interrogative pronoun available for i-structure interpretation in addition to information about the focus constituent and its scope.

(27) a. CP ⟶ XP IP
@(FocusQ ↑ ↓ (↓ WhPaths & WhPro)) ↑=↓
(↑ FocusPaths) = ↓

[3]Of course the original f-structure TOPIC attribute, should that be useful, can be easily resurrected by the alternative definition (i).

(i) TOPIC(*scope topic*) ≡ (*scope* TOPIC) = *topic*

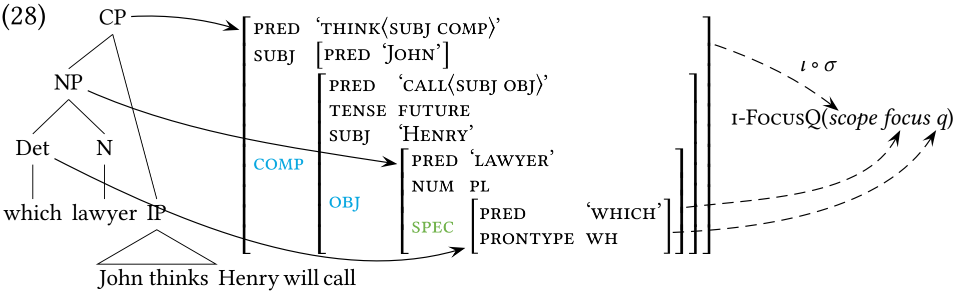
(ii) TOPIC(*scope topic/focus*) ≡ *topic* ∈ (*scope* DIS)

Definition (ii) produces the common DIS representation that Dalrymple et al. (2019) specify for both topic and focus. The set value suggests that syntactically the topic is not easily accessible.

b. FocusQ(*scope focus q*) ≡ @(i-FocusQ $scope_{\sigma\iota}$ $focus_{\sigma\iota}$ $q_{\sigma\iota}$)

This results in the relationships shown in (28) for the indirect question (17a).

(28)



There is no set-valued focus attribute and again no structure sharing in this simplified f-structure: the discourse entailments of this construction are off-loaded to the separate i-structure module. This is attractive because it exploits the Correspondence Architecture to simplify syntactic representations, but the full consequences of this arrangement remain to be investigated.

5 The *tough* construction

The English *tough* adjectives (*easy*, *hard*, *difficult*, *impossible*...) induce unbounded dependencies with only one uncertainty, as for topicalization, but they differ from both topicalization and constituent questions in that a single phrase contributes information to grammatical functions that are governed by predicates in two clauses. These adjectives subcategorize for a subject and an open *to*-complement. If the complement has a simple transitive predicate, the adjective's subject is understood as the complement's object and its object must otherwise not be realized. The basic pattern is displayed in (29).

(29) a. Moths seem tough to kill.
(cf. It seems tough to kill moths.)
b. Moths are tough (for someone) to kill.
c. * Moths are tough to kill moths.
d. * Moths are tough to arrive.

It is also generally accepted that the adjective's subj can serve as an obj in a clause embedded at an uncertain depth within the immediate complement, as illustrated by the examples in (30).

(30) a. Moths are tough to plan to kill.
b. This book is hard to get her to avoid reading. (Dalrymple & King 2000)
c. Kim would be difficult for me to persuade Robin to attempt to deal with. (Hukari & Levine 1991)
d. Mary is tough for me to believe that John would ever marry. (Kaplan & Bresnan 1982)
e. Kim is difficult to sit next to. (Grover 1995)

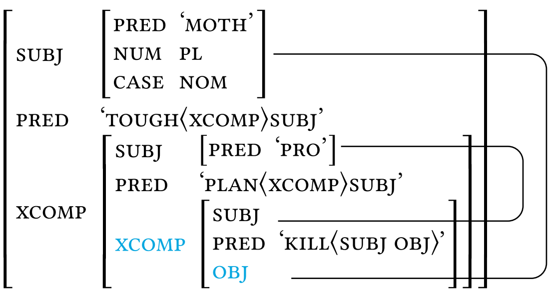
This unbounded dependency also differs from topicalization in that the uncertainty is keyed by the lexical entries of adjectives in this particular class rather than by a rule that describes a generic configuration of c-structure phrases. The uncertainty language itself is also quite different. The paths begin with sequences of XCOMPs that do not alternate with COMPs (31a-b), and they end only with OBJ, not just any non-COMP grammatical function (31c-d). The bottom OBJ can be preceded by an oblique (30c), a COMP (30d), or a member of a set of adjuncts (30e).

(31) a. * Mary is tough that John would ever marry.
b. * Mary is difficult for me to believe that John wanted to plan to marry.
c. * Tuesday would be difficult to take the exam. (Dalrymple & King 2000)
d. * Mary is tough for me to believe would ever marry John.

These possibiliites are expressed in the lexical uncertainty shown in (32).

(32) *tough* A (↑ PRED) = 'TOUGH⟨XCOMP⟩SUBJ'
(↑ SUBJ) = (↑ XCOMP TOUGHPATHS)
where TOUGHPATHS = XCOMP* {OBL_θ, COMP, ADJ ∈} OBJ

This gives rise to the outer connection shown in (33), the f-structure corresponding to sentence (30a) (the inner line indicates the local functional control relation for *plan*).

(33)


The *tough* uncertainty establishes an identity between the SUBJ of the adjective and an OBJ somewhere within its complement. The effect is that the predicate and all other f-structure properties of the matrix SUBJ appear also in the embedded OBJ. The examples in (34) suggest that this might lead to inconsistent values for a shared CASE feature.

(34) They/*Them are tough to kill.
It is tough to kill *they/them.

This connectivity problem has received some attention in the literature (e.g. Hukari & Levine 1991; Dalrymple & King 2000). Dalrymple & King 2000 proposed to avoid this problem by removing the functional identity of the two f-structure values. Rather than linking the *tough* SUBJ directly to an embedded OBJ, they depend on an obligatory anaphoric relation between the SUBJ and a grammaticized pronominal TOPIC in *tough*'s immediate complement. It is then the TOPIC f-structure that the uncertainty identifies with an embedded OBJ, as spelled out in (35a).[4] This two-step connection preserves the intended semantic entailments while the appeal to the referential component of grammar suppresses the propagation not only of CASE but also of all other syntactic features. The entry in (35b) achieves the same effect without relying on anaphora or an explicitly grammaticized TOPIC simply by asserting that the SUBJ and the embedded OBJ share only the same uniquely instantiated PRED.[5]

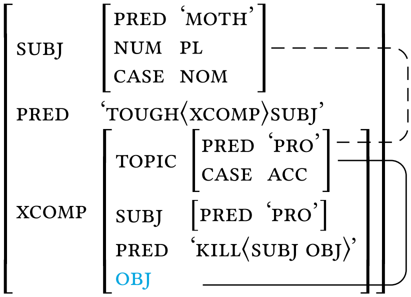
(35) a. *tough* A (↑ PRED) = 'TOUGH⟨XCOMP⟩SUBJ'
(↑ XCOMP TOPIC PRED) = 'PRO'
(↑ XCOMP TOPIC) = (↑ XCOMP ToughPaths)
b. *tough* A (↑ PRED) = 'TOUGH⟨XCOMP⟩SUBJ'
(↑ SUBJ PRED) = (↑ XCOMP ToughPaths PRED)
@(TOPIC (↑ XCOMP) (↑ SUBJ))

The lexical entry (35a) would assign the f-structure (36a) to sentence (29b), with the dashed lines representing an anaphoric relationship. Entry (35b) would assign the f-structure (36b).

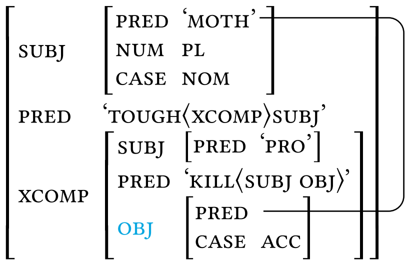
[4] Dalrymple & King (2000) assign the function COMP instead of XCOMP to the immediate complement, for reasons that are not relevant to the current discussion. They also argue that the *tough* SUBJ is thematic, but here I follow the raising/non-thematic representation suggested by Kaplan & Bresnan (1982). With respect to the issues of unbounded dependencies, this is also a difference of no consequence.

[5] Since SUBJ is generally assumed to map to a position of i-structure prominence, invoking the TOPIC template in (35b) may not be necessary for proper interpretation.

(36) a. Anaphoric binding to SUBJ



b. PRED sharing of SUBJ and OBJ



Each of these solutions supports the intended semantic interpretation while avoiding the CASE conflict. But each allows for free variation of all other syntactic features, even inherent features like gender or person that may enter into patterns of agreement that CASE does not participate in.

A more precise alternative is based on the restriction operator defined in (37). This permits relaxing the compatibility requirement for specific features (like CASE) while still enforcing consistency of all otherwise unmentioned features.

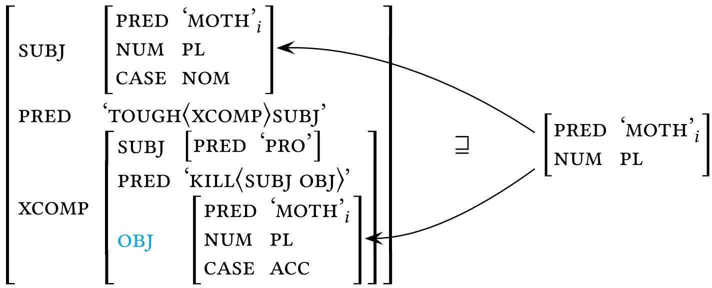
(37) Definition of restriction: (Kaplan & Wedekind 1993)
If f is an f-structure and a is an attribute, then the restriction of f by a is the f-structure $f\backslash_{a} = \{\langle s, v\rangle \in f \mid s \neq a\}$.

An f-structure f restricted by an attribute a contains all the attribute-value pairs of f except for the attribute a and its value. This formal device was used by Zaenen & Kaplan (2002) to suppress unwanted CASE conflicts in German functional control. It is applied in (38) to exclude CASE from the unbounded lexical uncertainty that holds between the *tough* SUBJ and the embedded OBJ. That particular incompatibility is thereby eliminated while all other features are shared (and may conflict).

(38) *tough* A (↑ PRED) = 'TOUGH⟨XCOMP⟩SUBJ'
(↑ SUBJ)$\backslash_{\text{CASE}}$ = (↑ XCOMP ToughPaths)$\backslash_{\text{CASE}}$
@(TOPIC (↑ XCOMP) (↑ SUBJ))

The logical f-structure relationships that the CASE restriction induces are shown explicitly in (39):

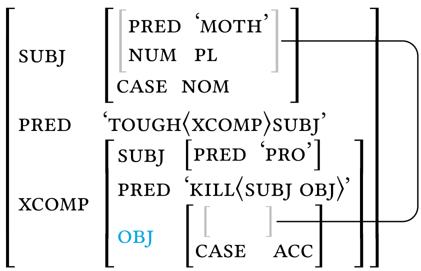
(39) Functional binding of CASE-restricted SUBJ



On the right is the CASE-restricted f-structure that is shared across the functional uncertainty. It subsumes the SUBJ and XCOMP OBJ values, causing them to have all of the same syntactic features except for CASE.

The same logical relations are depicted more intuitively with the abbreviatory graphical convention shown in (40). While the gray brackets in this diagram are not formally part of the linguistic representation, they highlight that the functional identity induced by the restricted unbounded dependency holds only between the enclosed proper subsets of the features of the SUBJ and XCOMP OBJ f-structures.

(40) Functional binding of CASE-restricted SUBJ (succinct)



In sum, the English *tough* construction involves an unbounded connection between two grammatical functions, the SUBJ in the matrix clause and an OBJ embedded in its complement. While this has the potential of creating an undesired f-structure conflict between the values of the clause-specific CASE features, that potential conflict can be avoided if an anaphoric relationship disrupts the functional identity across the clauses or if only the PRED value is shared. An alternative solution uses the f-structure restriction operator to suppress only the CASE feature without disturbing other patterns of agreement.

6 Relative Clauses

English relative clauses blend the double function assignments of the *tough* construction with the double uncertainties of constituent questions, as exemplified in (41).[6]

(41) The shop [[the owner of which] [Sue knows __]] sells books.

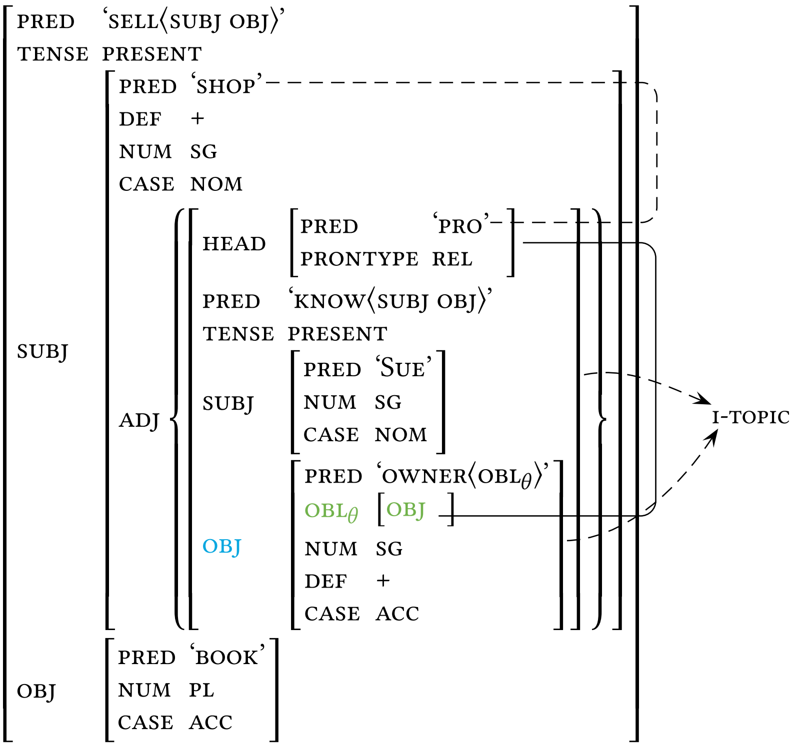
With respect to function assignments, *shop* is understood as both the subject of the matrix predicate *sells* and the (oblique) object of *owner*. With respect to uncertainties, the f-structure of the clause-initial *owner* phrase is the object of *knows* in this example but it could also bind to a function in a deeper complement. And the relative pronoun *which* can also appear at an arbitrary depth inside the clause-initial phrase. The examples (42a–42d) of what Ross (1967) called "Pied-piping" show some of the positions possible for the relative pronoun; example (42e) shows that the relative pronoun must appear somewhere.

(42) a. The man who we elected ...
b. The woman to whom we gave the book ...
c. The boy whose book Bill said was stolen ...
d. Reports the height of the lettering on the covers of which the government prescribes ... (Ross 1967)
e. * The shop the owner of the car Sue knows sells books.

F-structure (43) lays out the significant grammatical relationships of sentence (41). The uncertainty of the within-clause function for the clause-initial phrase is resolved by the blue OBJ path in RelTopicPaths, and that phrase also maps to the i-structure topic. The relative pronoun is identified as the HEAD of the clause (the solid line) by virtue of the attributes on the green path from RelHeadPaths. The dashed line between the HEAD and the nominal predicate indicates a connection of obligatory anaphoric control, as in the *tough* f-structure (36a), that avoids any CASE-like inconsistencies that might stem from the double function assignment.

[6]As mentioned earlier, the underscore indicating the position of the 'gap' is provided only as a reader's guide to the intended interpretation. As discussed in Section 7.3, it is quite a separate question whether it should also indicate the presence of an empty node in the syntactic representation.

(43)



This f-structure is derived by the rules and lexical entry in (44). According to rule (44a), the f-structure of a single relative clause is added to the adjunct set of the NP; the recursion through the NP category allows for NP’s with multiple clauses. Rule (44b) describes the internal structure of the relative clause itself. The f-structure of the clause-initial phrase is linked to its within-clause function through a path in RelTopicPaths and is also projected to the i-structure topic by the topic template. The head at the top is set to the relative pronoun required at the end of one of the RelHeadPaths. The dashed anaphoric connection is not established in the syntax.

(44) a. NP ⟶ NP CP
↑=↓ ↓∈ (↑ adj)

b. CP ⟶ XP C′
@(topic ↑ ↓) ↑=↓
(↑ RelTopicPaths) = ↓
(↑ head) = (↓ RelHeadPaths & RelPro)

where RelTopicPaths is {comp, xcomp, ...}* \comp
RelHeadPaths is {spec*, [(obl$_\theta$) obj]*}
RelPro is gf* gf
(→ prontype) $=_c$ rel

c. *which* Pro (↑ pred) = ‘pro’
(↑ prontype) = rel

Sentence (45) exemplifies a pattern for English relative clauses that is not derived by rule (44b).

(45) The books (that) the shop sells __ are expensive.

The embedded clause in this sentence does not begin with an external XP topic phrase. Rather, the XP position of (44b) is either filled with the complementizer *that* or is left completely empty, and in either case there is no explicit relative pronoun to trigger an anaphoric interpretation. The alternative CP expansion in (46) accounts for these c-structure configurations, simulates the anaphoric link by introducing a null pronoun, and identifies directly the within-clause function for the value of the head attribute.

(46) CP ⟶ *that* | *e* C′
@(topic ↑ (↑ head)) ↑=↓
(↑ RelTopicPaths) = (↑ head)
(↑ head pred) = ‘pro’

This produces (47) as the f-structure for the relativized matrix subject NP in (45) (now omitting the projection arrows that presumably map the head by default to the i-structure topic).

(47)
$$\left[\begin{array}{ll} \text{PRED} & \text{‘BOOK’} \\ \text{NUM} & \text{SG} \\ \text{DEF} & + \\ \text{CASE} & \text{NOM} \\ \text{ADJ} & \left\{\left[\begin{array}{ll} \text{HEAD} & \left[\text{PRED ‘PRO’}\right] \\ \text{PRED} & \text{‘SELL}\langle\text{SUBJ OBJ}\rangle\text{’} \\ \text{TENSE} & \text{PRESENT} \\ \text{SUBJ} & \left[\begin{array}{ll} \text{PRED} & \text{‘SHOP’} \\ \text{NUM} & \text{SG} \\ \text{DEF} & + \\ \text{CASE} & \text{NOM} \end{array}\right] \\ \text{OBJ} & \end{array}\right]\right\} \end{array}\right]$$

The HEAD ‘PRO’ is an essential ingredient of this commonly accepted analysis of relative clauses. On this account the semantic connection between the head noun and its role within the clause is established without a direct syntactic relationship. This has the advantage that unwanted inconsistencies of any double-function syntactic feature values cannot arise (cf. the anaphoric solution for *tough*). However, Falk (2010) puts forth several arguments against what he describes as this “anaphorically mediated” analysis.

On one line of attack he points to the contrast in (48). While the word *headway* in the idiom *make headway* can be the head of a relative clause (48a), it cannot otherwise be an antecedent for a referential pronoun (48b).

(48) a. Mary praised the headway that John made.
b. * Mary always praises headway when John makes it.

As another argument, he notes (citing Maxwell 1979) that languages with pronounless relative clauses are quite common among the 49 languages listed in the NP accessibility database of Keenan & Comrie (1979). He illustrates this with examples from a number of languages, including the ones in (49) (*that* is a complementizer in the English translations, not a pronoun).

(49) a. Hebrew (from Falk 2010)
meabed hatamlilim še Bill maadif.
processor DEF.texts COMP Bill prefers
‘the word processor that Bill prefers’

b. Japanese (from Keenan & Comrie 1979)
Watashi wa sono otoko ga tataita inu o miru.
I TOP that man NOM struck dog ACC see
‘I see the dog that the man struck.’

Some languages allow relative clauses with or without relative pronouns, like English, but relative pronouns simply do not exist in Japanese and other languages. Falk thus suggests that relative clauses without mediating pronouns are the typical case cross-linguistically, and that English examples like (41) are more the exception than the rule. A general account of head dependencies, he concludes, should not rely on the machinery of anaphoric binding.

Falk (2010) thus proposes an anaphorically-unmediated account of the connection between the f-structure of the relativized NP and the HEAD f-structure of the clause. The restriction operator is used to prevent selected features from clashing, along the lines of the *tough* analysis in (38) above. His proposal in essence is to augment the relative clause introduction rule (44a) with an equation that identifies the NP's (restricted) f-structure with the (restricted) HEAD of the clause (50).[7]

(50) NP ⟶ NP CP
↑=↓ ↓∈ (↑ ADJ)
$\uparrow\backslash_{\{\text{CASE, ADJ}\}} = (\downarrow \text{HEAD})\backslash_{\{\text{CASE, ADJ}\}}$

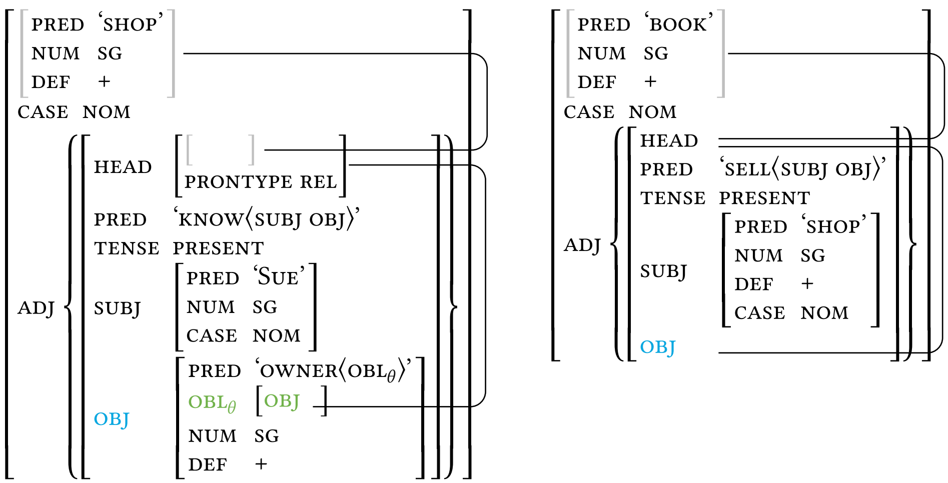
This permits the CASE feature of the NP and the relative HEAD to disagree; the relative-containing ADJ set is also restricted to avoid the technical confusion of circularity. The modified rule figures in the derivation of relative clauses with or without relative pronouns. English clauses with pronoun-containing initial XP phrases are still derived by rule (44b), but the relative pronoun no longer introduces its own pronominal PRED (51a). Instead the HEAD explicitly shares the head noun's PRED, thus establishing the semantic connection. Rule (46) is also simplified, since the null 'PRO' is not needed to compensate for the absence of an initial XP (51b).

(51) a. *which* Pro (↑ PRONTYPE) = REL

b. CP ⟶ *that* | *e* C′
@(TOPIC ↑ (↑ HEAD)) ↑=↓
(↑ HEAD) = (↑ RelTopicPaths)

With these revisions the f-structure (52a) is provided for the relativized NP *shop* in (41) and (52b) is provided for *book* in (45).

(52) a. b.



[7]The attribute HEAD is neutral with respect to Falk's semantically-oriented OPER attribute and the attribute RELPRO that aligns more with previous anaphora-based solutions.

In these structures the link between the restricted HEAD f-structures is strictly local. The links within the clause are unbounded, as indicated by the colored attributes from paths in the RelTopicPaths and RelHeadPaths uncertainty languages.

7 Further constraints on uncertainty paths

In modern LFG theory the admissibility of particular unbounded dependencies is determined first and foremost by the attribute strings in the uncertainty path-languages. But these dependencies have been challenging for linguistic description because they are also conditioned in different constructions and different languages by second-order interactions with other structural properties. Dependencies and the phrases they pass through must sometimes be aligned with respect to special morphological or phonological feature values (Section 7.1). Separate dependencies in some languages cannot pass through the same f-structures, giving rise to island effects (Section 7.2). Unbounded dependencies are of course related indirectly to word order by virtue of a grammar's normal c-structure rules and f-structure annotations, but they may also be sensitive to additional linear order constraints (Section 7.3).

7.1 Marking of intervening f-structures

Zaenen (1983) discussed a number of languages in which f-structures on a path between a filler and its clause-internal function differ in form from f-structures that are not in the domain of an unbounded dependency. She specifically considered Irish and Kikuyu, but since then many more cases have been discussed in the literature (see e.g. van Urk 2020). Here I focus on just the Irish examples of the phenomenon, as illustrated by the contrasts in (53) (data originally from McCloskey 1979).[8]

(53) Path-dependent complementizer selection in Irish

a. Deir siad goN/*aL síleann an t-athair goN/*aL bpósfaidh Síle é.
Say they that thinks the father that will-marry Sheila him
'They say that the father thinks Sheila will marry him.'

[8]In the linguistic literature the complementizer *a* is typically written as *aL* or *aN*, indicating that it triggers a lenition mutation or a nasalization mutation on the following word.

b. An fear aL/*goN deir siad a shíleann an t-athair aL/*goN
The man that say they that thinks the father that
phósfaidh Síle.
will-marry Sheila
'The man that they say that the father thinks Sheila will marry __.'

Embedded complements not on a binding path (53a) are introduced by the complementizer *goN* and not *aL*, while *aL* is required for complements that the relative-clause dependency passes through (53b). This pattern has a simple account if all and only intervening f-structures on a dependency path are marked with a distinguishing diacritic feature [UBD GAP] (for "gapped unbounded dependency"). That feature would then be available for checking by the complementizers' lexical annotations (54).[9]

(54) Irish complementizers

aL	C	(↑ UBD)
goN	C	¬(↑ UBD)

The positive existential constraint would not be satisfied if *aL* appears with a COMP that does not have a UBD feature, and the negative existential for *goN* would fail if that feature is present.

Working within the original Kaplan & Bresnan (1982) c-structure formulation of unbounded dependencies (Section 2.1), Zaenen (1983) added the f-structure marking feature (BND in her account) at sentential bounding nodes in a successive-cyclic fashion. In the modern functional framework, a basic uncertainty leaves no footprints as it passes through the intervening f-structures along a path, but its presence can be made known by adding off-path annotations to the attributes of the regular expression. Off-path constraints were formalized originally by Kaplan & Maxwell (1996) and Crouch et al. (2011); see also Dalrymple et al. (2019).

An off-path annotation is a functional description attached to an attribute in an ordinary functional designator, much like traditional descriptions are attached to c-structure categories. The difference is that an off-path annotation can use metavariables ← and → instead of (or in addition to) ↑ and ↓. These are instantiated to the f-structure containing the annotated attribute and the value of that attribute in the containing f-structure, respectively. A formal definition is given in (55).

[9] This is a respelling of the LDD ("long distance dependency") feature that appears in Dalrymple et al. (2019) and elsewhere. Ash Asudeh (p.c.) argues that UBD is a more accurate designation, since some instances of these constructions are actually quite short. Falk (2009) proposes a feature WHPATH for related path-marking purposes.

(55) Off-path annotations

$(f\ \underset{D}{a}) = v$ iff $(f\ a) = v$ and $D_{\substack{\leftarrow/f\\ \rightarrow/v}}$ is satisfied, where

D is a functional description and

$D_{\substack{\leftarrow/f\\ \rightarrow/v}}$ is the result of substituting f for $\leftarrow$ and v for $\rightarrow$ in D.

This definition extends the notation and meaning of primitive function-application designators (12a) and thus immediately carries over to the path languages of functional uncertainties (cf. (13a)).

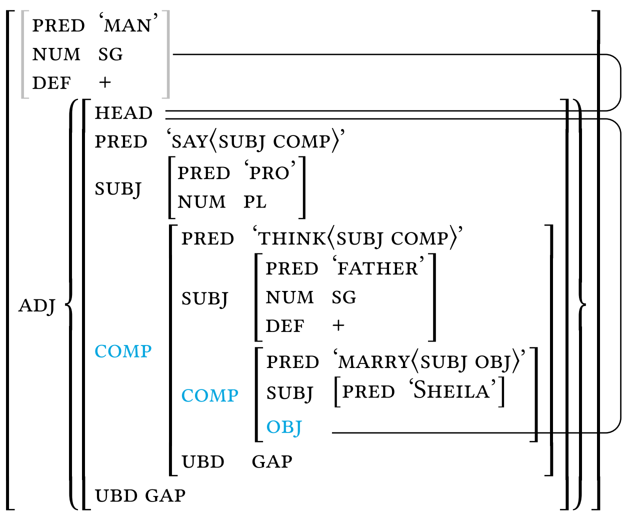
Off-path annotations were first used in a functional account of Irish complementizer marking that was developed in unpublished research by Mary Dalrymple, Ronald Kaplan, John Maxwell, and Annie Zaenen; Dalrymple (2001) provided the first published account of this approach. In essence, the uncertainty expression defined in (56a) inserts the UBD feature at every intervening f-structure without imposing any further restrictions on the grammatical functions along the path. The RelTopicPaths schema (56b) then applies regular-language intersection to mark the attributes of whatever path language is separately specified.

(56) a. Mark = $\underset{(\leftarrow\ \text{UBD}) = \text{GAP}}{\text{GF}^{*}}$ GF

b. RelTopicPaths = […] & Mark

The off-path annotation adds the UBD features parallel to the COMPs in (57), the f-structure for (the English gloss of) sentence (53b), and the lexical constraints (54) then assure the proper distribution of complementizers.

(57)



Asudeh (2012) discusses the more complicated relative clause patterns of Irish described by McCloskey (2002). Generally, the head nominal is assigned a within-clause function that has no surface realization (a gap), as in (57), if every intervening clause is marked with *aL*. But if the nasalization mutation triggered by *aN* appears at any clause along the way, then additional UBD marking is suspended and the head must bind to an explicit resumptive pronoun found in that clause or below. McCloskey (2002) illustrates this pattern with the relative clause in (58).

(58) Irish

aon	duine	a	cheap	sé	a	raibh	ruainne	tobak	aige
any	person	aL	thought	he	aN	was	scrap	tobacco	at-him

'anyone that he thought had a scrap of tobacco'

This motivates the more elaborate version of the marking language shown in (59a). Here the f-structures on an arbitrary (possibly empty) prefix of an uncertainty path are marked with the feature [UBD GAP], as before. But at any point along the path the marking value for embedded f-structures can optionally switch to RES(umptive). Intersecting the language RESOLVE in (59b) forces the uncertainty to resolve to a resumptive pronoun only when the RES value has been chosen.

(59) Irish gap marking (with resumptives)

a. $\text{MARK} = \underset{(\leftarrow\ \text{UBD})=\text{GAP}}{\text{GF}^*} \quad \Big(\underset{(\leftarrow\ \text{UBD})=\text{RES}}{\text{GF}^*} \Big)$

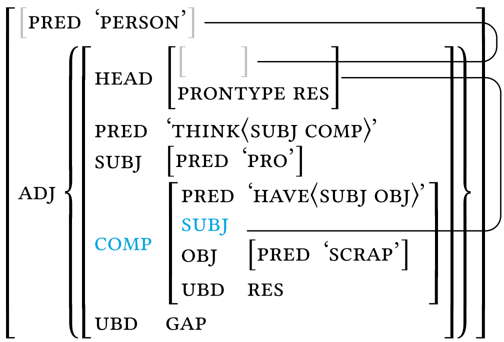
b. $\text{RESOLVE} = \text{GF}^* \quad \underset{(\leftarrow\ \text{UBD})=\text{RES}\ \text{iff}\ (\rightarrow\ \text{PRONTYPE})=_c \text{RES}}{\text{GF}}$

c. RELTOPICPATHS = […] & MARK & RESOLVE

The lexical annotations (60) then make sure that the complementizers along the way are properly correlated with how the uncertainty is resolved at the bottom.

(60)
aL C $(\uparrow \text{UBD}) =_c \text{GAP}$
aN C $(\uparrow \text{UBD}) =_c \text{RES}$

For the relative clause (58) this analysis gives rise to the abbreviated f-structure (61).

(61) 

Asudeh (2012) provides an alternative treatment of this and other patterns of Irish relatives. On his account the entire head f-structure, not just an atomic feature, is instantiated at every clause along the path. In this successive cyclic COMP-to-COMP arrangement, the head appears in the *aN*-complementizer clause in particular, and the pronoun binding is then set up there by a new uncertainty launched by *aN*'s lexical annotations. The marking strategy (59a), by comparison, offers the transition from gap to pronoun as a feature-controlled choice at any point within a single uncertainty language. It allows both the gap and the pronoun to be bound in the same end-to-end fashion, without any intermediate landing sites. This produces a less cluttered f-structure while making the claim that features of the particular head do not interact with properties of any intermediate clauses.

For Irish it is the selection of complementizers that interacts with unbounded dependency paths. The Kikuyu data cited by Zaenen (1983) and Dalrymple (2001) show that the verbs in intervening f-structures may also be sensitive to the presence of a dependency. This effect may be seen also in English: unbounded dependencies freely propagate through the complements of some verbs (62a) while (at least for some speakers) the complements of other verbs act as barriers (62b).

(62) a. Mary, we thought that Henry called.

b. * Mary, we whispered that Henry called.

Verbs like *think* are called bridge verbs, while *whisper* belongs to the class of nonbridge verbs. If the simpler MARK in (56a) is applied to the sets of English uncertainty paths, then the difference in behavior is accounted for by the negative existential in (63b).[10]

[10]Dalrymple et al. (2019) formalize the bridging restriction by pairing a negative defining equation $(\uparrow \text{LDD}) = -$ on *whisper* with an off-path negative value constraint $(\uparrow \text{LDD}) \neq -$ in the un-

(63) a. *think* V (↑ PRED) = 'THINK⟨SUBJ COMP⟩'

b. *whisper* V (↑ PRED) = 'WHISPER⟨SUBJ COMP⟩'
¬(↑ UBD)

This captures the syntactic difference between bridge and nonbridge verbs, but that difference may be a structural reflection of a more basic semantic or pragmatic difference. Erteschik-Shir (1973) suggested that verbs that imply the manner of saying something are more likely to form islands than verbs that simply describe what is being said. It is not clear whether the various constraints on unbounded dependencies that can be formalized with LFG's syntactic machinery are better explained by appeal to other components of grammar, or to principles of cognition, pragmatics, or computation.

In these illustrations the unbounded dependency announces itself by the value it defines for the special UBD feature, and that value can then be examined to limit the f-structures that the dependency passes through. English adjuncts appear to interact with unbounded dependencies in a different way. Sentence (64a) was cited earlier to show that adjuncts can be topicalized and that the topicalization path-language (for English, not Icelandic) should include ADJ (∈) as an option. But the ungrammaticality of example (64c) indicates that an additional restriction must be imposed on the general pattern (examples from Dalrymple 2001).

(64) a. This room Julius teaches his class in __.

b. We think that David laughed after we selected Chris.

c. * Chris, we think that David laughed after we selected __.

This difference has been ascribed to the fact that the ADJ clause is tensed in (64c) but not (64a), although there may be other pragmatic or semantic factors also at work (see Toivonen 2021 and references cited there).

Taking the bridge verbs as a model, tensed adjuncts could be excluded from unbounded dependencies by adding a negative existential constraint ¬(↑ UBD) to every tensed verb. But it is more economical to leave all the verbs alone and instead to refine just the uncertainty so that it cannot pass to or through a tense-marked ADJ element. The path language (65a) and the intersection (65b) impose that constraint on TopicPaths (Dalrymple 2001 and Dalrymple et al. 2019 formulate TAC in a slightly different but equivalent way).

certainty. The LDD feature thus always appears in the complement f-structures of nonbridge verbs, even if not in the context of an unbounded dependency. In the solution outlined here that feature appears always and only along a dependency path and is available there for the bridge verb to test.

(65) Tensed Adjunct Constraint[11]

a. $\mathrm{TAC} = \backslash[\ \underset{(\to\ \in\ \mathrm{TENSE})}{\mathrm{ADJ}}\ ]^*$

b. $\mathrm{TopicPaths} = [\ \{\mathrm{COMP}, \mathrm{XCOMP}, \mathrm{ADJ}\ (\in)\}^*\ \backslash\mathrm{COMP}]\ \&\ \mathrm{MARK}\ \&\ \mathrm{TAC}$

The TAC restriction can be applied with a similar intersection to FocusPaths and the path languages of other constructions, as appropriate.

However, examples (66) indicate that grammaticality is not correlated with the presence of absence of the TENSE feature. The participial adjunct in (66a) is untensed and therefore the inadmissible dependency in (66b) would not be ruled out by the Tensed Adjunct Constraint.

(66) a. The cat slept after devouring the rat.

b. * What did the cat sleep after devouring __?

Instead, what is common to the ungrammatical examples in (64) and (66) is the presence of a subject, either derived from an explicit phrase (64c) or inserted as an anaphorically controlled null pronoun (66b). Unbounded dependencies may thus be more sensitive to the constraint as formulated in (67).

(67) Subject Adjunct Constraint

$\mathrm{SAC} = \backslash[\ \underset{(\to\ \in\ \mathrm{SUBJ})}{\mathrm{ADJ}}\ ]^*$

Like many other conditions, restrictions on adjunct dependencies seem to be language-particular and not universal. Swedish for example seems to be more flexible than English in this regard (see Müller 2019). It is an advantage of the LFG approach that such constraints can be expressed easily within the formalism without appeal to extragrammatical (and often false) general principles.

7.2 Classical island constraints

Early interest in unbounded dependencies was mainly stimulated by the constraints on them that were first described in detail by Ross (1967). Working within a framework of transformational rules, Ross gave a list of "island" configurations that block the movement of constituents from one clause to another. He observed in particular that sentential subjects, coordinate structures, and complex NPs all seem to interfere with unbounded relationships, as the contrasts in (68) suggest (after Ross 1967).

[11] Intersection and term-complementation of off-path annotations can be reduced to more primitive expressions by noting the equivalences of $\underset{D_1}{a}\ \&\ \underset{D_2}{a}$ and $\underset{D_1 \wedge D_2}{a}$ and of $\backslash[\ \underset{D}{a}\ ]$ and $\{\underset{D}{\backslash a}, \underset{\neg D}{a}\}$.

(68) Sentential Subject Constraint

a. The reporters expected that the principal would fire some teacher.

b. The teacher who the reporters expected that the principal would fire __ …

c. That the principal would fire some teacher was expected by the reporters.

d. * The teacher who that the principal would fire __ was expected by the reporters …

Coordinate Structure Constraint

e. Henry plays the lute and sings madrigals.

f. * The lute which Henry plays __ and sings madrigals …

g. * The madrigals which Henry plays the lute and sings __ …

Complex NP Constraint

h. Phineas knows a girl who __ is jealous of Maxime.

i. * Who does Phineas know a girl who __ is jealous of __?

j. * Maxime, Phineas knows a girl who __ is jealous of __.

It appeared that transformations cannot move the constituents of sentential subjects (68a–68d), that parts of individual conjuncts in a coordination cannot be moved (68e–68g), and that the complex NPs of relative clauses also form a barrier (68h–68j). Ross formulated these island constraints in phrase-structure terms and appealed to extra-grammatical (and presumably universal) stipulations to impose them on the otherwise unfettered operation of individual transformational rules.

Later transformational accounts maintained the view that unbounded dependencies are allowed except when they would cross into phrasal islands, and this conception was carried over into the early c-structure-based LFG approach. Kaplan & Bresnan (1982) and Zaenen (1983) provided a grammar-internal way of limiting the range of the bounded-domination metavariables $\Uparrow$ and $\Downarrow$ and thus enabled more fine-grained characterizations of island configurations. They permitted particular categories in c-structure rules to be marked as “bounding categories”, and nodes licensed by those categories were not allowed on the dominance paths connecting co-instantiations of $\Uparrow$ and $\Downarrow$. For example, the ungrammaticality of (68i) would follow on that theory if the CP under NP in rule (44a) is marked as a bounding category. But there is no need for such categorial distinctions in the modern LFG theory of unbounded dependencies, since the vocabulary of grammatical functions and features provides a natural platform for expressing such island-like restrictions.

Ross' Sentential Subject Constraint, for instance, can be expressed by the term-complement formula (69a). This defines paths of arbitrary length that do not pass through subjects and that bottom out in any grammatical function. And the constraint could then be enforced by intersecting this with any other long distance regular language, as in (69b). Any paths with SUBJ-containing prefixes would no longer be available.

(69) a. SSC = \SUBJ* GF
  b. RELTOPICPATHS = […] & SSC (English)
  c. RELTOPICPATHS = SUBJ+ (Tagalog)

This restriction would be helpful for English relatives if there is an explanatory advantage in stating the basic path language in a simple but overly general way (e.g. [GF* \COMP]). But it would not be needed if the regular expression for the basic uncertainty defines the admissible paths more precisely. Either way, this is clearly not a universal constraint: Kroeger (1993) observes that the path language for Tagalog unbounded dependencies contains *only* subjects, as in (69c). Such an extragrammatical condition may have been the only way of regulating the operation of transformational rules, but it serves no particular purpose in the setting of functional uncertainty.

Coordinate structures in LFG are represented formally as conjunct-containing sets under distributive attributes, and their behavior with respect to f-structure well-formedness is specified in (12e), repeated here for convenience. A set satisfies a distributive f-structure property if all of its elements satisfy that property. While this account of coordination is defined only for local f-structure configurations, unbounded dependencies simply inherit that local behavior by virtue of the incremental, single-attribute expansion of functional uncertainty as spelled out in (13a), also repeated.

(12e) $(f\ a) = v$ iff f is a set and
  $(g\ a) = v$ for all $g \in f$ if a is a distributive attribute
  $\langle a, v\rangle \in f$ if a is a nondistributive attribute.

(13a) If PATHS is a set of attribute strings,
  $(f\ \text{PATHS}) = v$ iff $((f\ a)\ \mathit{Suff}(a, \text{PATHS})) = v$.

The pattern of coordinate structure violations illustrated in (68e-g), and in (10) above, follows immediately from this independent theory of coordination: without further stipulation, a dependency that crosses into a coordination cannot affect just one of the conjuncts.[12]

An NP is "complex" for Ross if it immediately dominates a clausal category (CP now, S as originally formulated). The essence of the Complex NP Constraint is that no unbounded dependency can relate an element outside such an NP to an element inside the dominated clause. Examples (68i) and (68j) are ungrammatical on this theory because the relativized NPs are complex in this way and thus are opaque to the question and topicalization dependencies. Our framework offers a different account of their ill-formedness: the clauses are represented in f-structure as adjuncts of the head noun *girl* and so do not satisfy Subject Adjunct Constraint installed in the English FocusPaths and TopicPaths path sets. As noted above, tac is not universal, it applies in English but not for instance to Swedish dependencies. It is not surprising that the Complex NP Constraint also does not seem to operate in Swedish (Müller 2019).

The CNPC characterizes English relative clauses (with assignments to adj) as islands for unbounded dependencies. It does not cover other cases where dependencies seem to be mutually exclusive. Example (70b) shows that two question dependencies cannot overlap, (70c) shows that a topicalization cannot pass into a question, and (70d) shows that a question also obstructs a relative clause dependency. None of these involve complex NPs.

(70) a. Phineas wonders which girl is jealous of Maxime.
b. * Who does Phineas wonder which girl __ is jealous of __?
c. * Maxime, Phineas wondered which girl __ is jealous of __.
d. * The girl that Phineas wondered who __ is jealous of __ left.

On one approach the path languages for each of the outer dependencies can be conditioned against tell-tale properties of the innner question f-structure, presuming that those are recognizable and independently motivated (for example,

[12]The suffix language for a chosen attribute must propagate into each conjunct, but Kaplan & Zaenen (1989) note that the residual uncertainties are then not required to resolve all in the same way:

(i) Mary, John expected to see __ and give the book to __.

Here the set of xcomp suffix paths resolves to obj in the first complement but obl_θ in the second. In contrast, Saiki (1985) observes that some Japanese relative clauses are constrained so that the dependencies in all conjuncts must resolve either to a subject or to a non-subject. This constraint can be imposed by intersecting [gf* subj | gf* \subj] with the basic Japanese path specification.

if a grammaticized FOCUS attribute is still needed for some other reason). Falk (2009) proposes instead to make use of the path-marking feature UBD (his WH-PATH) that is already needed for verb and complementizer selection. It is the inner construction that then determines whether to protect itself from other unbounded dependencies. English embedded questions thus become dependency islands when a negative UBD constraint is added to the rule (71) that introduces them.

(71) CP ⟶ XP IP
@(FocusQ ↑ ↓ (↓ WhPaths & WhPro)) ↑=↓
(↑ FocusPaths) = ↓
¬(↑ UBD)

It may not be an accident that the constraint that blocks an outer unbounded dependency co-occurs with an equation that launches an inner one, as in this rule. Some but not all languages may use this as a strategy to keep at bay the confusion of too many overlapping uncertainties.

7.3 Constraints on linear order

In the unbounded dependency constructions examined so far, an uncertainty is launched from an overt c-structure constituent or lexical item and binds the content of that element to a remote position in f-structure. The uncertainty is outside-in for most of the constructions, where the external element is realized perhaps far away from the normal c-structure location of its within-clause function assignment. The uncertainty is inside-out when the overt element of a dependency is in situ, as in the Mandarin example (21). These purely functional accounts go through without making reference to c-structure positions that correspond to the other, covert ends (bottom or top) of the dependencies. So far there has been no need for the phonologically empty nodes or traces that have been an essential ingredient of other theories of syntactic binding.

However, there are well known cases to suggest that the bottom end of an outside-in uncertainty must be grounded at a specific c-structure position, that the external element must be associated with a within-clause c-structure position in addition to a within-clause function. The weak crossover pattern in (72), first discussed by Wasow (1979), has received the most attention. Controlling for other possibly relevant factors, this shows an interaction between the linear position of the pronoun and the within-clause position where the OBJ or OBL_θ function assigned to *who* would normally be expressed. The pronoun *his* and *who* cannot refer to the same individual if the pronoun comes before the assumed within-clause position of *who*:

(72) Weak crossover (examples from Dalrymple et al. 2001)

a. * Who$_i$ did his$_i$ mother greet __?
   (cannot mean: Whose$_i$ mother greeted him$_i$?)

b. * Who$_i$ did Sue talk to his$_i$ mother about __?

c. Who$_i$ did Sue talk to __ about his$_i$ mother ?

The English contrast in (73) has also been taken as evidence that within-clause locations must be assigned to the external elements of question and *tough* constructions (see Kaplan & Bresnan (1982) and references cited therein). Sentence (73b) is uninterpretable because the link from *sonata* to its putative within-clause position crosses over the link from the overt appearance of *violin* to its covert linear position.

(73) Nested syntactic dependencies

a. Which violin is this sonata easy to play __ on __.

b. * Which sonata is that violin easy to play __ on __.

The ordering patterns illustrated by these examples are not found in all languages. Maling & Zaenen (1982), for example, note that crossing dependencies are acceptable in Norwegian and only dispreferred in Swedish. It must therefore be possible to parameterize or otherwise express these restrictions in the grammars of individual languages.

7.3.1 Ordering by (empty) trace nodes

Bresnan (2001) proposed to handle the linear ordering facts of weak crossover within a larger cross-linguistic theory of anaphoric binding.[13] She expands the NP at the within-clause position to an empty string, and then arranges for the ϕ

[13] For the general theory of anaphoric binding this proposal is part of, see Rákosi forthcoming [this volume]. On the Bresnan (2001) theory a pronominal cannot be more "prominent" than its potential antecedents, where prominence for a given language may be based on relative positions on a hierarchy of grammatical functions (SUBJ is more prominent than OBJ), on a hierarchy of thematic roles (AGENT is more prominent than PATIENT), or on the linear order of corresponding c-structure nodes. Only the linear prominence condition is relevant for these particular examples of weak crossover in English.

correspondence function to map both the trace node and the NP at *who* to the same f-structure (e.g. OBJ or OBL_θ). That many-to-one correspondence is set up by converting the uncertainty from outside-in to inside-out and shifting its launch site to the new trace node, as illustrated in (74).[14]

(74) a. CP ⟶ XP IP
@(FocusQ ↑ ↓ (↓ WhPaths & WhPro)) ↑=↓
~~(↑ FocusPaths) = ↓~~
¬(↑ UBD)

b. NP ⟶ *e*
↑= (FocusPaths ↑)

With node mappings set up in this way, the weak crossover constraint on linear order can be stated in terms of the f(unctional)-precedence relation defined in (75): a pronoun cannot f-precede its antecedent.[15]

(75) Functional precedence Bresnan (2001)
f f-precedes g ($f <_f g$) iff the rightmost node in $\varphi^{-1}(f)$ c-precedes the rightmost node in $\varphi^{-1}(g)$.

However, separating the uncertainty specification from the dependency's overt element comes at a descriptive cost. Without some further stipulation the grammar would accept a phrase in the XP position of (74a) even when it corresponds to no FocusPath trace node in the clause c-structure and thus is assigned no within-clause function. This issue has been addressed by introducing a global condition on well formed f-structures, the Extended Coherence Condition. This was first proposed by Zaenen (1985); this version is taken from Dalrymple (2001):[16]

[14]This analysis was also carried over into Bresnan et al. (2016), but the later co-authors are not in full agreement about the status of empty elements and whether dependencies should run outside-in or inside-out (Ash Asudeh, p.c.).

[15]Bresnan's f-precedence definition (75) differs from the proposals of other authors. It compares the positions of only the right-most nodes of the inverse-ϕ images, while Kaplan & Zaenen (1989) and others take into account all nodes in the correspondence.

(i) Functional precedence (Kaplan & Zaenen 1989)
$f <_f g$ iff for all $n_1 \in \varphi^{-1}(f)$ and all $n_2 \in \varphi^{-1}(g)$, n_1 c-precedes n_2 ($n_1 <_c n_2$).

These definitions are equivalent for purposes of this discussion.

[16]If grammaticized discourse functions are not represented in f-structure, the intuition behind this constraint would have to be reformulated as a condition on i-structure correspondences.

(76) Extended Coherence Condition
FOCUS and TOPIC must be linked to the semantic predicate argument structure of the sentence in which they occur, either by functionally or anaphorically binding an argument.

This important requirement can be reconstrued as a well-formedness condition on grammars rather than on representations. Functional binding is guaranteed if a simple existential constraint (77) is attached by convention as an additional annotation to the filler XP in (74a).

(77) Extended coherence constraint
$(\text{GF}\ \downarrow)$

Depending on how the relationships of anaphoric binding are made formally explicit, a similar constraint can be defined for those linkages.

Another convention is needed to prevent the proliferation of trace nodes at different c-structure positions whose inside-out uncertainties would bind a single filler to the same or different within-clause functions (but see Section 8). One motivation for Bresnan's Economy of Expression principle (78) is to exclude derivations that contain such unwarranted trace bindings.[17]

(78) Economy of Expression (Bresnan et al. 2016)
All syntactic phrase structure nodes are optional and are not used unless required by independent principles (completeness, coherence, semantic expressivity).

Extended Coherence and Economy help to control the promiscuous behavior of trace-launched uncertainties, those that are not directly associated with overt triggering configurations.[18]

[17] Separately, Dalrymple et al. (2015) present a critical discussion of Economy as a general principle of syntax.

[18] Although it has not been explored in the literature and I am not advocating for it here, there is a trace-based alternative that may be somewhat less unattractive. On this analysis the trace is used only to establish a within-clause linear position for the uncertainty: it does not serve as a launching site. The uncertainty remains with the overt external element, but each path language (e.g. FocusPaths) is intersected with the off-path annotations in Locate (i) to guarantee that it ends at a function assigned at a c-structure trace node. The bookkeeping feature TRACE is defined at all and only trace nodes.

(i) $$\text{Locate} = \text{GF}^{*} \quad \begin{array}{c}\text{GF}\\ (\rightarrow\ \text{TRACE})\\ (\rightarrow\ \text{UBD}) = \text{GAP}\end{array} \qquad \text{NP} \longrightarrow \begin{array}{c} e \\ (\uparrow\ \text{TRACE}) = + \\ (\uparrow\ \text{UBD})\end{array}$$

As a final observation, it is also not clear whether or how well the Bresnan account of weak crossover ordering extends to characterize the nested dependency pattern in examples (73), given that the path languages for the question and *tough* constructions are not the same. Careful regulation of empty-node ordering offered a solution to the *sonata/violin* contrast in the original LFG theory of unbounded dependencies (Kaplan & Bresnan 1982), but the c-structure stipulations of that theory do not naturally carry over to the path languages of modern approaches.

7.3.2 Ordering by coarguments

Dalrymple et al. (2001) use a different definition of linear prominence based on the notion of coargumenthood and a relation between the pronoun and the f-structure that contains the wh-term (called the "operator"). With this formulation they show that the linear order constraints of weak crossover can be modeled without appealing to traces. They define coarguments as the arguments and adjuncts of a single predicate[19] and propose that both of the following prominence conditions must be satisfied:

(79) Let CoargOp and CoargPro be coargument f-structures such that CoargOp contains the within-clause function of the operator (wh-term) and CoargPro contains the pronoun. Then:

Syntactic [= Functional] Prominence: An operator O is more prominent than a pronoun P if and only if CoargOp is at least as high as CoargPro on the functional hierarchy.

Linear Prominence: An operator O is more prominent than a pronoun P if and only if CoargOp f-precedes CoargPro.

The key idea is that Linear Prominence depends on the f-precedence relations of the coarguments, the clause-internal f-structure sisters that contain the operator and pronoun. The positions of the nodes that the outside-in uncertainty maps to the coarguments in the weak crossover example (72a) are indicated in (80a). Note that CoargOp is located only at the leading position because its function OBJ is not projected from any clause-internal (trace) node. This sentence meets the Linear Prominence requirement, but fails the Syntactic Prominence test because OBJ is lower than SUBJ on the function hierarchy.

[19]Dalrymple et al. (2019) note that "co-dependent" may be a more accurate label for this concept, since adjuncts are included along with arguments. Here I continue to use the terminology of the original paper.

(80) a. * Who$_i$ did [his$_i$ mother] greet?
CoargOp CoargPro

b. * Who$_i$ did Sue talk [to his$_i$ mother] about?
CoargPro CoargOp

c. Who$_i$ did Sue talk to [about his$_i$ mother]?
CoargOp CoargPro

For examples (72b) and (72c) the oblique functions are at the same position on the functional hierarchy so they both meet the Syntactic Prominence condition. This grammaticality difference follows from the locations of the within-clause coargument nodes as annotated in (80b) and (80c) respectively. CoargPro is the OBL_{TO} of *talk* in (80b) (because *his* is contained in the *to*-phrase) and CoargOp is the $\text{OBL}_{\text{ABOUT}}$ (because the outside-in uncertainty resolves to that function). The sentence is ungrammatical because the nodes mapping to CoargPro and CoargOp are in the wrong order. The Coargs and their order are switched in the grammatical sentence (80c).

On this proposal, the operator's within-clause function is first determined by an outside-in uncertainty. After that the coarguments are identified in the clause at which the paths to the operator and pronoun functions first diverge. Linear order is then defined on the nodes that map to those overt, lexicalized coargument functions. Weak crossover is the target of this particular account, but coargument precedence may apply more generally. The nested dependency constraint (73) may follow from a different coargument ordering requirement once the coargument functions are identified for the *violin* and *sonata* phrases.

(81) a. [Which violin] is [this sonata] easy to play on?
1 2/Coarg2 Coarg1

b. * [Which sonata] is [that violin] easy to play on?
1/Coarg1 2 Coarg2

The formal details of such an ordering principle have not yet been worked out.

7.3.3 Ordering by subcategorizing PREDicates

The subcategorizing predicate for a given grammatical function is the semantic form that licenses that function in a local f-structure, via the Coherence and Completeness conditions. The value of those conditions in linguistic description is obvious, but Kaplan & Maxwell (1988a) noted that they are also key to the computationally efficient resolution of functional uncertainties. A typical uncertainty allows for the full array of grammatical functions each of which must be hypothesized in principle at every level of embedding. The overall computational complexity is much reduced if that exploration is deferred until the subcategorizing predicate is reached: the possible realizations can then be limited to all and only the functions that it governs. Kaplan (1989a) made a related psycholinguistic processing observation: the results of early trace-inspired measures of word-by-word cognitive load experiments (Kaplan 1974; Wanner & Maratsos 1978) could also be attributed to additional activity when the subcategorizing predicate is first encountered. It was not recognized in these early studies that subcategorizing predicates could also be the basis for a trace-free account of linear order grammaticality conditions.

Pickering & Barry (1991) made a much more systematic sentence-processing argument that overt subcategorizing predicates and not empty categories determine how external elements are integrated into embedded clauses. Adopting their Direct Association Hypothesis, Dalrymple & King (2013) sketch an account of nested dependencies that depends on the linear order of the predicates that subcategorize for the bottom functions of overlapping uncertainty paths. They use the term "anchor" for the subcategorizing predicate of the bottom function, as illustrated in (82).[20]

(82) Anchor ordering

a. [Which violin] is [this sonata] easy to play on?
1 2 Anchor2 Anchor1

b. * [Which sonata] is [this violin] easy to play on?
1 2 Anchor1 Anchor2

In (82a) *violin* is anchored at the *on* predicate, as indicated by the arrow, because the outer uncertainty resolves to *on*'s OBJ. Similarly, the anchor for *sonata* is *play*. The anchoring predicates are the same in (82b), but they occur in the opposite linear order. Dalrymple and King make precise what it means for two dependencies to interact (intuitively, that the outer dependency unfolds through a clause containing the inner one). The difference between (82a) and (82b) then follows from their nesting condition: if two dependencies 1 and 2 interact, then Anchor1 must not precede Anchor2. Nadathur (2013) accounts for the linear order of weak crossover by a separate anchor-ordering constraint: the anchor of the operator must precede the pronoun.

[20]This notion of "anchor" should not be confused with the formal definition used in the decidability proofs for LFG parsing and generation Kaplan & Wedekind forthcoming [this volume].

Although Dalrymple & King (2013) and Nadathur (2013) do not give a detailed specification of their outside-in, anchor-based approaches to linear order, the basic notions are easy to represent within the existing LFG formalism. First, the anchor of an uncertainty path is the PRED of the f-structure one up from the bottom. The off-path annotation on the path language (83) picks out that PRED and adds it as a diacritic feature to the f-structure at the top of the path, where the uncertainty is launched.

(83) $\textsc{Anchor} = \textsc{gf}^{*} \underset{(\uparrow\ \textsc{anc}) = (\leftarrow\ \textsc{pred})}{\textsc{gf}}$

The effect of intersecting ANCHOR with any other path language (e.g. FOCUSPATHS or TOUGHPATHS) is to make the within-clause anchor directly available at the top, presumably at the operator's f-structure.

Second, PRED semantic forms in LFG are composite entities that encapsulate succinctly a collection of syntactic and semantic properties. These are accessible by distinguished attributes REL, ARG1, ARG2, etc. Semantic forms are also instantiated, and Kaplan & Wedekind forthcoming [this volume] make explicit that the instantiating index of a PRED is the value of another distinguished attribute SOURCE. Moreover, the value of SOURCE is the daughter node, formally denoted by $*$, at which the PRED is introduced into the f-description. Thus a defining equation (84) is implicitly carried along with every PRED.

(84) PRED instantiation (from Kaplan & Wedekind forthcoming [this volume])
$(\uparrow \textsc{pred source}) = *$

A PRED-precedence relation (85) follows naturally from the immediate connection between instantiated semantic forms and c-structure nodes: semantic forms are ordered by the c-structure order of their instantiation SOURCE nodes.

(85) PRED precedence
$p_1 <_p p_2$ iff $(p_1\ \textsc{source}) <_c (p_2\ \textsc{source})$.

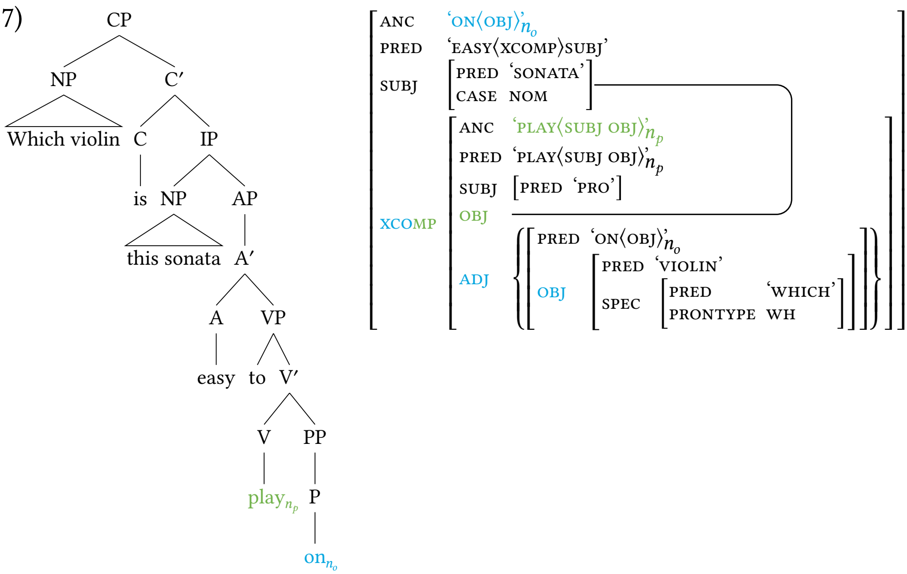
This is a simpler relation than f-precedence since it is defined directly on singleton nodes, not on ϕ^{-1} sets of nodes. Finally, the path language (86) encodes the nested-order constraint.

(86) $\textsc{Nested} = \underset{(\uparrow\ \textsc{anc}) \nless_p (\rightarrow\ \textsc{anc})}{\textsc{gf}^{*}}\ \textsc{gf}$

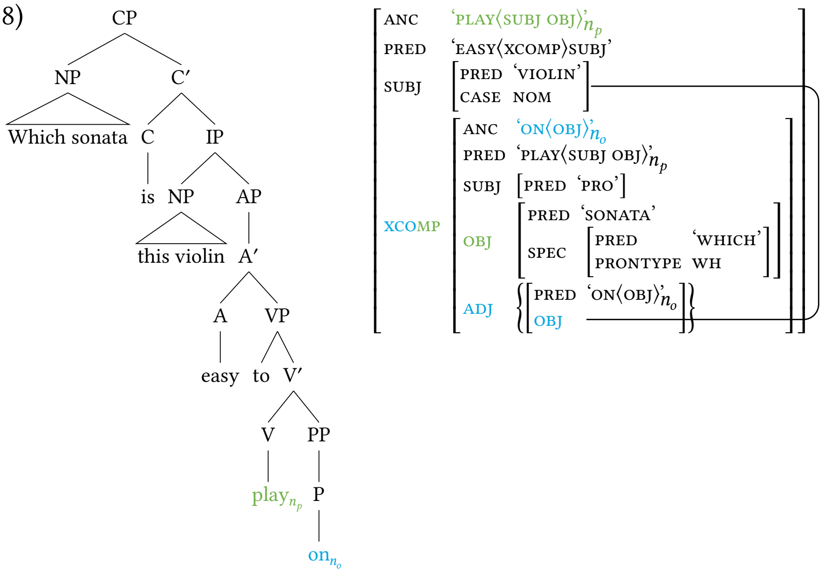
($\uparrow$ ANC) is the anchor of the outer uncertainty (*on* in (82a), *play* in (82b)). That remains constant as the uncertainty unfolds. If the outer uncertainty (the *wh* phrase) overlaps an inner uncertainty (*easy*), the ordering condition will compare their two anchors. The nesting follows from the fact that the hierarchical positions of the anchors in f-structure are reversed relative to the linear c-structure order. The nested-order constraint can be imposed (for a language where it applies) by intersecting (86) with the path languages for the various constructions.

The c-structure and f-structures for the nested sentence (82a) are sketched in (87). The attributes and anchor are blue for the outer question dependency and green for the inner *easy* dependency. The outer path overlaps the inner path at the XCOMP of *easy* and then diverges. At that point (↑ ANC) in the question uncertainty denotes the *on* semantic form with source node n_o and the source of (→ ANC), the *play* form, is node n_p. The nesting test succeeds because n_o does not precede n_p. For the ungrammatical (82b) the anchors are reversed (88) and the test fails.

(87)



(88)



8 Multiple gap constructions

It is unremarkable in LFG that a given subsidiary f-structure may appear as the values of several attributes at different levels inside a higher structure. This is a consequence of the equality relation in functional descriptions and is the basis for accounts of functional control, agreement, distributed coordination, and the unbounded dependency of *tough* adjectives (and other unbounded dependencies if grammaticized discourse functions are retained in f-structure). Other identities might be consistent with the set of assertions in an f-description, but the linguistically-relevant minimal models contain only those that follow from the basic propositions and the transitivity of equality. This simple picture is violated by the well-known instances wherein a single unbounded-dependency filler appears to resolve to more than one (uncoordinated) within-clause grammatical function (in LFG terms) or somehow binds to more than one trace position (in other frameworks).

Sentence (89) from Engdahl (1983) is a paradigmatic example of such a multiple gap dependency.

(89) Which articles did John file __ without reading __?

This is understood as asking about a particular set of articles that were filed by John but not read by him. The second gap is usually described as “parasitic” on the first because of the contrast in (90) (following the literature, the parasitic gap is now labeled with the subscript *p*).

(90) a. * Which articles did John file the book without reading $\_\__p$?

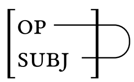
b. Which articles did John file __ without reading more than their titles?

Example (90a) is ungrammatical for the usual reason that its putative gap is in an island-forming adjunct with respect to unbounded dependencies (in an LFG analysis its FocusPaths uncertainty would not satisfy the path language sac, the Subject Adjunct Constraint (67)). (89) shows that that barrier is inactive in the presence of the earlier gap, and (90b) shows that resolving to the direct object does not require the support of an adjunct gap.

Multigap dependencies have received relatively little attention in LFG compared to other grammatical frameworks. If an outside-in uncertainty is used to characterize an unbounded dependency, the natural interpretation is that the minimal model for the resulting f-description will establish only one within-clause function for the clause-initial phrase. And even if some technical adjustment is made to allow for multiple function assignments in general, it would still be necessary to account for the fact that the sac constraint of the normal FocusPaths can be abrogated just in (89) and similar multigap configurations.

Alsina (2008) discusses parasitic gaps in the context of a new general architecture for structure sharing in LFG. On his proposal the f-structure for a sentence is not the minimal model for an f-description derived from the annotations of particular c-structure rules. Rather, the universe of all formally well-formed f-structures, with unlimited structure-sharing relationships, is filtered by a collection of restrictive principles, and the sentence is assigned all and only the f-structures that are not thereby eliminated. As an example, the filter (91a) disallows structure-sharing of an op and subj at the same level (recall that op(erator) is the undifferentiating attribute that Alsina uses to represent the filler in f-structure).

(91) Alsina's (2008) "Same-clause op-subj ban"

a. *


b. For all f-structures f, (f op) ≠ (f subj).

A formal expression of this principle is given in (91b). The basic proposition is expressed in the ordinary notation of functional annotations. But this differs from the annotations of the conventional LFG architecture in that the f-structure variable is instantiated by universal quantification over the space of all f-structures and not by mapping particular c-structure nodes through the ϕ correspondence. Alsina (2008) argues that this new architecture and the set of principles he puts forward can provide a unified treatment of bounded (raising) and unbounded dependencies, and that appropriate f-structures can be assigned to sentences with parasitic gaps. This architecture and its principles have not yet been widely adopted, however.

Falk (2011) addresses the multigap problem by an alternative analysis within the conventional LFG architecture. He reasons that if a single uncertainty can license only one dependency and if a sentence has multiple dependencies for one filler, then the f-description for that sentence must have multiple uncertainties. Further, since the number of dependencies in a multigap sentence is determined by the number of within-clause functions assigned to a given filler, the uncertainties for those dependencies must be introduced inside-out at each of the gap locations and not outside-in at the single clause-initial phrase. Thus, he proposes a trace-based, inside-out analysis that freely anticipates any number of unbounded dependencies, even though there may be no local evidence to trigger the empty c-structure nodes. Falk reviews much of the literature on parasitic gaps and other multiple gap constructions, suggesting that many of their restrictions are due to mixtures of pragmatic and processing factors and others are the result of syntactic constraints carried by the inside-out uncertainty paths with their off-path annotations.

The key fact about parasitic gaps is that they are, indeed, parasitic. That fact is not exploited directly by either the Alsina (2008) or Falk (2011) solutions to the multigap problem. In an intuitively straightforward account, an outside-in uncertainty launched at the filler phrase would resolve to the main gap (OBJ in (89)) in the ordinary one-to-one way. But then, optionally, a secondary uncertainty would be launched to bind that same filler also to the grammatical function of the parasitic gap. This is what happens if the PARA path language (92a) is imposed by intersection on the FOCUSPATHS uncertainty (92b).

(92) a. PARA = $\text{GF}^{*} \quad \underset{(\rightarrow\, =\, (\leftarrow\ \text{ADJ} \in \text{GF}^{+}))}{\backslash\text{SUBJ}}$

b. FOCUSPATHS = [...] & PARA & SAC

If FOCUSPATHS resolves to a non-SUBJ within-clause function, the right arrow → in the optional off-path annotation denotes the top-level filler f-structure. Thus, if the option is taken, this equation launches a new uncertainty that must resolve to some function inside one of the elements of an ADJ set. By virtue of the left arrow ←, that ADJ must be an f-structure sister of the non-SUBJ. The non-SUBJ restriction is included in this example to illustrate one way of accounting for the ungrammaticality of (93); obviously, other factors may also be at work.

(93) * Which articles did you say __ got filed by John without him reading $\_\__p$?
(from Engdahl 1983)

The underlying idea of this solution is that a single filler can be bound to two gaps within an outside-in, one-to-one setting if one uncertainty is allowed to launch another one. The details of an analysis along these lines remain to be developed.

In fact, Falk (2011) notes that parasitic gaps may be a special case of a more general pattern of multiple-gap constructions. Sentences (94b–94c) show that each of the gaps in (94a) can be filled without the support of the other one.

(94)
a. Who did you tell __ that you would visit __ ?
b. Who did you tell __ that you would visit your brother?
c. Who did you tell your brother that you would visit __ ?

This pattern can be assimilated to the PARA outside-in off-path solution simply by enlarging the path language of the secondary uncertainty. For this example COMP OBJ would be added as an alternative to the paths beginning with ADJ. There is still an asymmetry between the dependencies for the two gaps: only the primary uncertainty (resolving to the shorter path) is launched from the top, while the secondary one is optionally introduced at the bottom of the first. On this theory what distinguishes adjunct parasitic gaps from other multiple gap examples is just the adjunct island created by the intersection of SAC with the primary path language; that constraint is not incorporated into the secondary uncertainty.[21]

[21]Further research and consideration of more examples might show that multiple gaps operate symmetrically and that the sequential chaining of secondary uncertainties is therefore inadequate. That would add weight to Falk's (2011) preference for an inside-out solution. Another possibility, indifferent as to inside-out or outside-in, is to extend the interpretation of uncertainty languages in general so that multiple gaps are no longer seen as exceptional:

(i) Multi-gap functional uncertainty
If PATHS is a set of attribute strings and $\varnothing \subset \mathrm{P} \subseteq \mathit{Pref}(\mathrm{PATHS})$,
$(f\ \mathrm{PATHS}) = v$ iff $((f\ a)\ \ \mathit{Suff}(a, \mathrm{PATHS})) = v$ for all $a \in \mathrm{P}$
where $\mathit{Pref}(\mathrm{PATHS}) = \{a \mid a\sigma \in \mathrm{PATHS}\}$.
(the set of single-attribute prefixes of strings in PATHS)

A subset P of the available attributes would be selected at each point as an uncertainty unfolds, and the uncertain suffix of each of those attributes must recursively resolve. This is an easy adjustment, technically, but it may be difficult to define path languages so that P subsets properly handle any cross-path interactions.

9 Summary

Unbounded dependencies interact in complicated ways with the syntactic properties that define the local organization of clauses and sentences. This chapter provides a sample, clearly incomplete, of the many theoretical and empirical issues that have been discussed in the LFG literature and in the linguistic literature more broadly. The earliest LFG approaches to such dependencies were modeled after the phrase structure solutions of other frameworks, but it is now generally recognized that the functional configurations enshrined in f-structure support the most natural and direct descriptions and explanations. Accounts based directly on f-structure were made possible by extending the basic LFG formalism with the technical device of functional uncertainty.

Functional uncertainty permits the backbone dependencies of topicalization, constituent questions, relative clauses, and the *tough* construction to be stated as regular languages containing the f-structure paths that connect fillers to their within-clause functions. But unbounded dependencies are additionally challenging because they can be sensitive to various features of the f-structures they pass through. The intervening f-structures may be marked in distinctive ways, they may form dependency-blocking islands, and there may be restrictions based on linear order. This chapter has suggested that many of these ancillary effects can be accounted for by attaching off-path annotations to the uncertainty-path attributes.

In sum, the combination of functional uncertainty with off-path annotations is an expressive tool for describing the rich and varied properties of unbounded dependencies. It integrates well with the other formal devices of LFG theory, and it is the foundation for modern LFG treatments of these phenomena.

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