The Syntax of Coordination and Discontinuity in a Combinatory Categorial Grammar

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Abstract. This paper proposes a new analysis in a Combinatory Categorial Grammar (CCG) of long-known coordination and discontinuity data in English. The analysis is based on the *wrap* operation first proposed by Bach (1979). It goes on to explore new data relating to Heavy-NP Shift and particle verbs, and a discontinuous coordination phenomenon known as Right-Node Wrapping (Whitman 2009). Finally it demonstrates that all these data are natural consequences of the present analysis.

Keywords: Categorial Grammar, Coordination, Right-Node Raising, Right-Node Wrapping, Discontinuity, Wrap, Syntax, Semantics

1 Introduction

This paper explores two domains which present unique challenges to the familiar notion of constituency: coordination phenomena and the hypothesis of discontinuous constituency. Among the coordination phenomena considered here are so-called Right-Node Raising (RNR) and Non-Constituent Coordination (NCC). The hypotheses of discontinuity has its origins in early Transformational Grammar, but was reiterated in Categorial Grammar by Bach (1979, 1981).

Of particular interest in the present discussion is the phenomenon recently dubbed "Right-Node Wrapping" (RNW) (Whitman 2009), a discontinuous coordination phenomenon. In RNW sentences, the right conjunct of the coordination is discontinuous (1) (in this and the following examples discontinuous constituents are underlined). RNW brings to the foreground questions about the nature of constituency and the organization of the grammar.

(1) Bach fetched and gave the oboe to Telemann.

2 Combinatory Categorial Grammar (CCG)

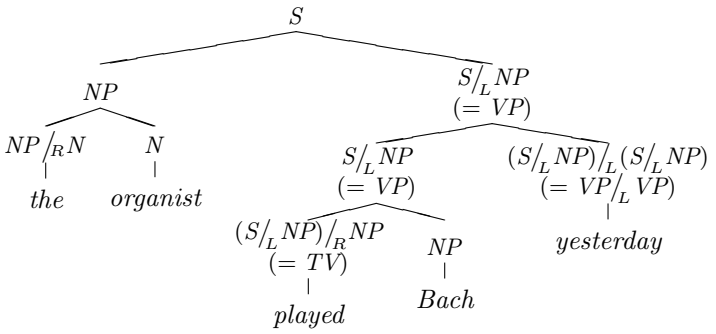
CCGs are a family of monostratal (i.e. non-transformational) frameworks, originating in the logical tradition of Ajudkiewicz (1935) and Bar-Hillel (1953). Its original formulation was discovered to be weakly equivalent to Phrase-Structure Grammars (Bar-Hillel, Gaifman and Shamir 1960). The 1980s saw natural extensions to the framework allowing it to account for a wide variety of phenomena

on the syntax-semantics interface, including unbounded dependencies, gapping, and Dutch cross-serial dependencies (see, for example, Steedman 2000).

The foundational insight behind CCG is that Phrase-Structure Rules and Subcategorization Frames can be combined by assigning expressions complex and informative syntactic categories. Specifically, expressions of category A/B includes all expressions which subcategorize for and combine with B type expressions to give A type expressions. Subscripts L and R on the slash indicate that the argument combines to the left and right of the expression, respectively. As an aside, this is the notation found in, e.g. Jacobson (2014); subscripts are not used in the related Type Logical tradition or by Steedman (e.g. 2000).

For instance, all *VP*s, including all intransitive verbs, can instead be given the category $S/_L NP$, as they combine with a subject to their left to give a sentence. Likewise, transitive verbs have the category $(S/_L NP)/_R NP$, and *VP* adjuncts are $(S/_L NP)/_L(S/_L NP)$. These complex categories can be used to prove the well-formedness of sentences as in (2) (here and in other figures *VP* and *TV* are shorthand for $S/_L NP$ and $(S/_L NP)/_R NP$, respectively). The full set of categories can be recursively defined as either a primitive category — *NP* (noun phrases and proper names), *N* (common nouns), *S*, *PP*, *CP* — or a complex category $A/_L B$ or $A/_R B$ where A and B are any two categories (primitive or complex).

(2)



In the CG view, slash categories like $S/_L NP$ correspond to functions, and so they combine with their arguments via function application (**FA**), defined in (3). In prose, (3) states that an $A/_L B$ combines with a B to its left to give an A, and likewise an $A/_R B$ combines with a B to its right to give an A.

(3) **FA**: $B \;\; A/_L B \;\Rightarrow\; A$ $\qquad\qquad$ $A/_R B \;\; B \;\Rightarrow\; A$

In the CCG adopted in this paper, **FA** is just one of a few combinatory rules for building expressions. The two additional combinators are unary type-shift rules which allow the framework to describe more complex phenomena.

Type Lifting (**L**), the next rule, shifts an argument of some type into functions over arguments of that type (4). In other words, an A may shift to a $B/_R(B/_L A)$ or a $B/_L(B/_R A)$.

(4) **L**: $A \;\Rightarrow\; B/_L(B/_R A)$ $\qquad\qquad$ $A \;\Rightarrow\; B/_R(B/_L A)$

The final combinatory rule Geach (**G**) (also called "Division" in some texts) shifts both sides of a slash category into functions over the same type (5). i.e. an A/B can shift to an $(A/C)/(B/C)$ as long as all the slashes are the same. The reader is referred to Jacobson (2014) for more explanation on the use of these combinators, and the status of **G** as opposed to the nearly equivalent Function Composition combinator found in other CCGs.

(5) **G**: $A/_L B \Rightarrow (A/_L C)/_L(B/_L C) \qquad A/_R B \Rightarrow (A/_R C)/_R(B/_R C)$

Both of these type shift rules are formulated so that they are word-order preserving, i.e. they allow for the same strings that can be proven well-formed with plain, context-free **FA** to be alternately proven with different constituency. Indeed, with a sufficiently general statement of all the combinatory rules, *any* constituency that results in the same string is possible (Moortgat 1988).

Combinatory rules, of which these three are the most typical, are the complete grammar. Since they only involve simple operations on strings — prefix and postfix concatenation — the grammar does not refer to complex objects such as trees to formulate operations like movement or to impose configurational constraints. That is, CCG is monostratal, while remaining descriptively powerful. This is true of the semantics as well, though space does not permit a detailed account. A great advantage of CCG is that the syntactic category of an expression corresponds directly to its semantic type. As a result, a direct compositional semantics follows naturally from a CCG. The addition of a couple combinatory rules allows for adequate accounts of quantifier scope (Partee and Rooth 1982), binding (Jacobson 1999), and extraction (Steedman 2000), *inter alia*. There is no need for a CCG to "remember" a tree for applying complex structural rules like quantifier raising, or configurational constraints like Principles A, B and C. Rather, the compositional semantics can be built up "dumbly" alongside syntactic strings.

3 Non-Constituent Coordination

One of the greatest successes of the CCG outlined above is its natural account of Right-Node Raising (RNR) (Ross 1967, Postal 1974), and more generally Non-Constituent Coordination (NCC), which Dowty (1988) showed follows directly from the three combinatory rules.

Perplexing for theories with a traditional notion of constituency, it seems almost any substring of a sentence can be coordinated with a like substring, whether or not they are "canonical" constituents (6) (Dowty 1997). This paper refers to the coordinated expressions as *conjuncts* (shown in square brackets), and the material "belonging to" both conjuncts as the *pivot* (shown in bold). In RNR, the pivot is on the right of the conjuncts (6a), while NCC includes all cases in which conjuncts are non-canonical constituents. Elliptical or phonological deletion-based accounts for RNR like Conjunction Reduction (Hudson 1976) and Linearization-Based Deletion (Chaves 2014) can generate these unusual conjuncts

via reduction of “full" conjuncts. That is, the pivot is present in both conjuncts at some level of representation, but deleted under identity in one (7).

(6) a. [Bach composed] and [Leipzig adored] **arias with soprano soloists**.

b. **Bach played** [cantatas on Sunday] and [sonatas at night].

(7) [Bach composed ~~cantatas with soprano soloists~~] and [Leipzig adored cantatas with soprano soloists].

These accounts fail to capture cases in which the pivot obtains wide quantificational scope (6a) (Bachrach and Katzir 2006), or the conjuncts are interpreted cumulatively by the pivot (6b) (Barros and Vicente 2011). Their inadequacy stems from the fact that the semantics of the full conjuncts is incompatible with the full range of possible readings. Therefore, they are forced to analyze these semantic data as phenomena unrelated to ordinary RNR. Such accounts frequently require extended notions of constituency like Multidominance in which one expression has multiple parents (McCawley 1982, Barros and Vicente 2011) and Across-the-Board (ATB) extraction in which multiple extracted expressions “combine" into one (Williams 1978, Chaves 2014). Even more oddly, cases in which two conjuncts share some expression to their left (the mirror image of RNR) (6b), are not consequences of most RNR accounts (e.g. Chaves 2014).

(8) a. [Glenn Gould played piano on], or [Scott Ross played harpsichord on] **every piece in the first complete collaborative recording of the Bach preludes**. ($\forall \succ \vee$)

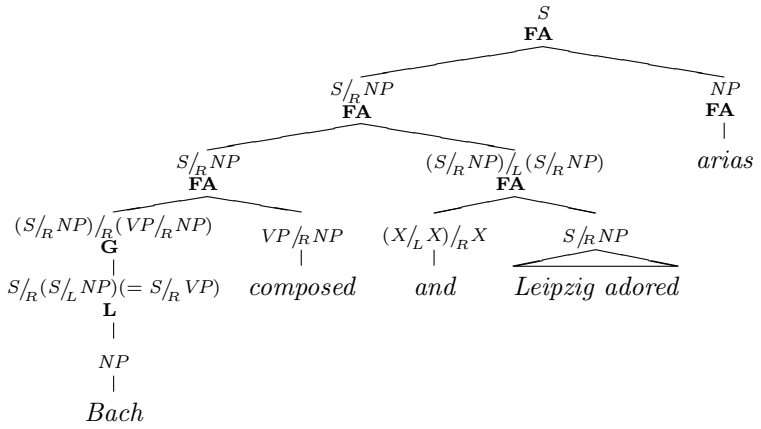
b. [The organist played] and [Mary heard] different fugues. $\neq$ [The organist played ~~different fugues~~] and [Mary heard different fugues].

By contrast, all these facts about coordination are accounted for entirely *for free* by the interaction of the three combinatory rules of CCG. Conjunctions such as *and* have the category $(X/_L X)/_R X$ where X is a variable over categories. This category simply ensures that the conjuncts are of like-categories. CCG predicts only unary- and binary-branching, so coordination is not assigned a flat structure. Since English prefers head-first word order (a generalization noted in, e.g. X-bar Theory), the conjunction first combines with the right conjunct. This is not necessarily a bad prediction, as just such an expression can be found as fragment utterances, as in e.g. the discourse (9).

(9) Speaker A: Did Bach ever set the St. Matthew Passion text?
Speaker B: Yes. And the St. John Passion text, too.

Standard RNR is possible (10), as is leftward sharing by the conjuncts (11).

(10)



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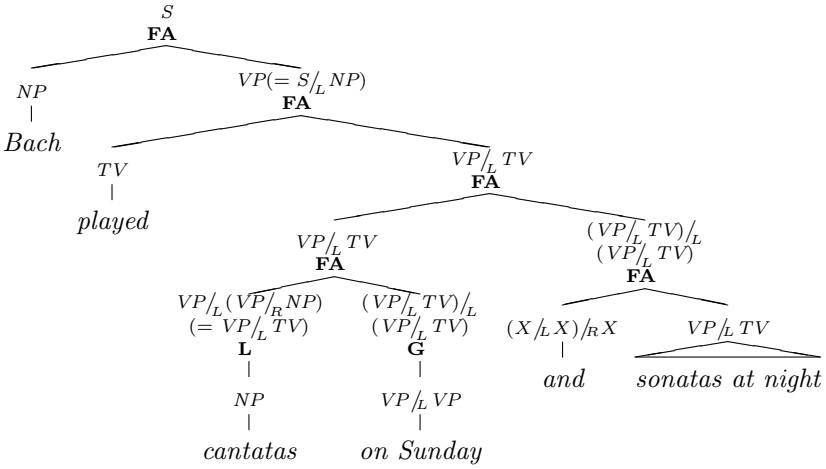


Recall $VP{=}\ S/_L NP$ and $TV{=}\ (S/_L NP)/_R VP$.

Even RNR in which the pivot is itself not a canonical constituent (12) is possible (though space does not permit a proof). This case is difficult for transformational or movement accounts because the transformation cannot simply be applied to a single constituent. CCG's direct compositionality also accounts for the scopal ambiguities of RNR (8) with the correct sequence of generalized **L** and **G**. Conjuncts which cross clause boundaries (13) are provable in CCG as well.

(12) [Bach composed] and [Leipzig adored] **cantatas on Sunday**.

(13) Frederick the Great [thought that Bach was unable to improvise] and [indeed never thought he would hear] **a six voice fugue**.

Since in a completely flexible CCG any substring of sentence can be shown to be a constituent, this account predicts that any such substrings of the same category may be coordinated. This appears to be a serious overgeneration, as it fails to account for the reported unacceptability of certain coordinations. Awkward

coordinations in which the pivot is on the left edge (14a) and the right edge (14b) have both been noted (Dowty 1997, Chaves 2008). Chaves (2014) points out that encliticization appears to block RNR (15a), and Phillips (2003) notes that certain linear strings which cross clausal adjunct boundaries are odd in coordination 15b).

(14) a. ***Books about** [math are dull] and [poetry are not]. (Chaves's *)
b. *[The relatives of the bride in] and [the relatives of the groom behind] **the front pews have not been introduced yet**. (Dowty's *)

(15) a. ?*[John thinks that she'd] and [Bill knows that she'll] **show up**.
b. *After Wallace fed [his dog the postman], and [his sheep the milkman] **arrived**. (Phillips's *)

Though it is not the primary goal of this paper to respond to these concerns, it is worth pointing out that apparent overgenerations in the syntax are to be expected. Strings which are licensed by the syntax may fail to be well-formed on pragmatic or prosodic grounds — or may fail under native speaker judgments on the basis of processing. For example, the sentences in (15) are greatly improved with different prosody despite similar syntax (16). Which of these grammatical hurdles a particular string or utterance may fail to clear is not a question that native speakers can introspect on.

(16) a. [John thinks that she would] and [Bill knows that she will] **show up**.
b. They [arrived after Wallace fed] and [left before Wallace played with] **his purebred Dachshund**.

4 Discontinuity

CCG offers a powerfully flexible notion of constituency, which makes largely successful predictions about English coordination data. The CCG outlined in section 2 is able to assign constituency to any *continuous* substring of a sentence, however it does not show any *discontinuous* strings to be constituents.

Nonetheless, discontinuous constituencies have been hypothesized in the syntactic literature at least since Chomsky (1957), who proposed that (17) is derived from (18), and many of these original arguments for discontinuity are still valid today.

(17) John found the boy studying in the library.

(18) John —found studying in the library —the boy

4.1 Old data

Discontinuity in English is most commonly proposed to account for three-place predicates, though a wide variety of phenomena have been analyzed with discontinuous constituency.

(19) a. *particle verbs*: look the record up (Dowty 1997 ; Morrill 1995)
b. *ditransitives*: donate the book to the library (Dowty 1997)
c. *tough-adjectives*: John is a tough man to please (Dowty 1997)
d. *comparatives*: Amanda is more clever than John is (Dowty 1997 ; Moortgat 1996)
e. *degree modifiers*: The plate is too hot to handle (Dowty 1997)
f. *resultatives*: break the geode open
g. *discontinuous idioms*: give the man the cold shoulder (Morrill 1995)
h. *coordination particles*: Mary either walks or talks (Morrill 1995)

Particularly robust data that support the hypothesis of discontinuous three-place verbs comes from weak crossover asymmetries in pronoun binding. For a ditransitive like *give*, a pronoun in the rightmost object may be bound by a *NP* in the leftmost object (20), but not vice-versa (21). Whether pronoun binding is licensed by a notion like c-command, or a direct-compositional approach like Jacobson's (1999) variable-free semantics, these data demand that the verb combines first not with the argument immediately to its right, but with the one farther from it, forming a discontinuous constituent.

(20) a. Bach gave every soprano$_i$ her$_i$ score on Friday.
b. Bach gave every score$_i$ to its$_i$ owner on Friday.

(21) a. *Bach gave its$_i$ owner every score$_i$ on Friday.
b. *Bach gave her$_i$ score to every soprano$_i$ on Friday.

This discontinuous constituency is the conclusion arrived at not only in some CCG literature, but in the Government and Binding framework as well, due to Larson (1988). Just as in the CCG analysis, Larson proposes that expressions like *gave to its owner* form a constituent in D-Structure and move into their surface configuration to give (20b). As we shall see, CCG accounts like the one to follow obtain the desired constituency without resorting to movement.

4.2 New formalization

This section formalizes a discontinuous CCG that is adequate for describing the discontinuity data above. The present system borrows the names of two discontinuous operations on strings —- *wrap* and *infix* — from Bach (1979, 1981, 1984) who originated the analysis of passives and control in a discontinuous CCG, but the proposal here is entirely original.

The intuition behind this calculus is that some strings in the syntax have an *infixation point* notated as "$\vert$" somewhere inside them (including possibly on the edge). A discontinuous constituent may *wrap* around another constituent, splitting at its infixation point. The *infix* operation inserts a constituent inside a discontinuous constituent, using the infixation point as the locus of insertion. If the infixation point is on the edge of an expression, then *wrap* is vacuous — it

appears superficially like concatenation. Justification for supposing that vacuous *wrap* occurs is discussed later.

Together with *left-* and *right-concatenation*, these discontinuous operations comprise the only ways in which strings combine to form larger expressions in this system. The strings of function and argument *left-* or *right-concatenate* when the function has a $/_L$ or a $/_R$, respectively. Likewise, *wrap* and *infix* have their own slashes: $/_W$ and $/_I$.

As defined so far, the operations *wrap* and *infix* break down if the discontinuous constituent contains more than one infixation point. So the behavior of the operations must be better defined to prevent an expression from containing more than one infixation point at a time.

1. *concatenation* of two continuous strings gives a continuous string.
2. *concatenation* of a continuous and a discontinuous string gives a discontinuous string with the same infixation point as the original discontinuous string.
3. *concatenation* of two discontinuous strings gives a discontinuous string which retains the discontinuity of whichever expression had the functor category.
4. A continuous string cannot *wrap* around another string (and a string may not *infix* into a continuous string).
5. *wrap*-ping a discontinuous around a continuous string (or *infix*-ing a continuous into a discontinuous string) gives a continuous string.
6. *wrap*-ping or *infix*-ing two discontinuous strings gives a discontinuous string which retains the discontinuity of the infix, not the wrapper.

Note that none of these operations *create* infixation points. Infixation points must then originate with lexical items, but I will stipulate that whether a lexical item has an infixation point is entirely predictable from its category. This generalization suggests a lexical rule **I** (22), which equips a continuous lexical item with an infixation point on its right edge if it is a transitive or ditransitive verb (these two cases could be combined with a recursive rule), and makes it take its direct object by *wrap*.

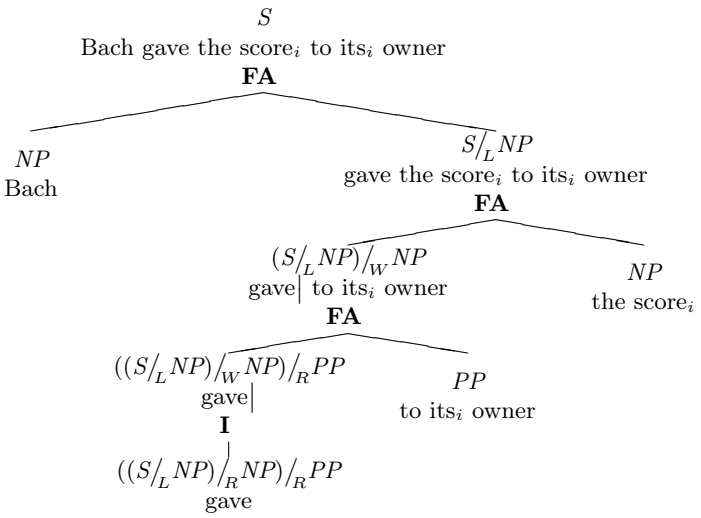
(22) **I**: For all (continuous) words with phonology a:

a. $a : (S/_L NP)/_R X \;\Rightarrow\; a\big| : (S/_L NP)/_W X$

b. $a : ((S/_L NP)/_R X)/_R Y \;\Rightarrow\; a\big| : ((S/_L NP)/_W X)/_R Y$

So after applying **I**, transitives like *compose*$\big|$ have the category $(S/_L NP)/_W NP$, and ditransitives like *give*$\big|$ are $((S/_L NP)/_W NP)/_R PP$, giving structures like (23). Note that (23) is just the right configuration (or in direct compositional terms, order of arguments) to account for the binding data in (20-21).

(23)



This discontinuous CCG also provides a highly natural account of heavy NP shift like (24). Before the application of **I**, the category of *give* is $((S/_L NP)/_R NP)/_R PP$. Heavy NP shift is obtained by not applying **I**, and instead using the above category. Note that in (24) since the order of arguments (or the c-command relations) are the same as in (23) the binding phenomena are still accounted for, despite appearing on the surface like (21a).

(24) Bach gave to its$_i$ owner the score$_i$ (with all the markings from rehearsal).

Particle movement also falls out from **I**. Productive particles like *out* appear to attach to verbs with any valency, warranting the category $((S/_L NP)...)/_L((S/_L NP)...)$ (where "..." is any sequence of arguments, including none, and is the same on both sides). Furthermore suppose that *out* only takes as argument phonological words, and the verb and particle together form a phonological word (see e.g. Zwicky (1992) for discussion on "words" in syntax). Applying **I** after the particle combines with the verb gets the continuous particle verb (25a), while applying **I** before gets the discontinuous pattern (25b). Therefore, not all transitive verbs which undergo **I** are vacuous *wrap*-pers.

(25) a. Bach <u>wrote out</u> the parts.

b. Bach <u>wrote</u> the parts <u>out</u>.

The ditransitive particle verb data (26a-b) discussed in Emonds (1972, 1976) falls out by the same mechanism, while (26c) is not generated, as the rule **I** would have to apply twice to get both arguments to *wrap* in, which violates the constraints on **I**.

(26) a. Bach sent out the parts to the singers.

b. Bach sent the parts out to the singers.

c. *Bach sent the parts to the singers out.

d. Bach sent out to the singers the parts (that he copied yesterday).

e. *Bach sent to the singers out the parts (that he copied yesterday).

f. *Bach sent to the singers (the parts that he copied yesterday) out.

The interaction between heavy NP shift and particle movement (26d-f) has not been discussed previously in the syntactic literature as far as I know. Strikingly, these data are entirely predicted by the present account. In order to get the heavy NP shift pattern, **I** must never apply, giving the continuous particle-verb pair (26d) and ruling out the discontinuous ones (26e-f).

5 Right-Node Wrapping (RNW)

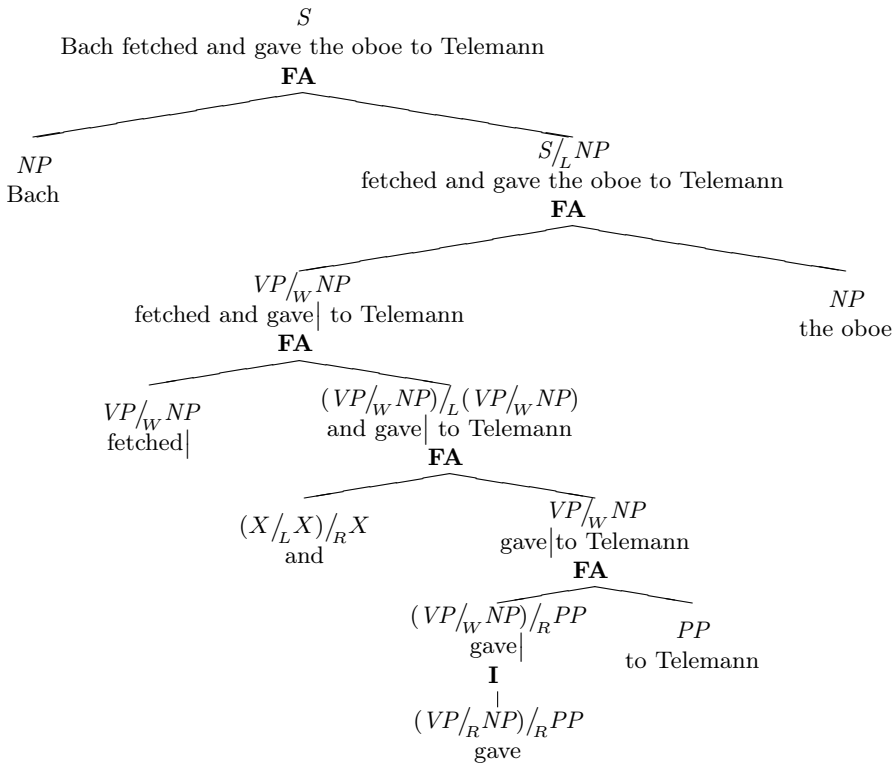
The phenomenon of Right-Node Wrapping (RNW) first discussed in Whitman (2009) is another natural consequence of this discontinuous CCG. RNW is related to RNR, but instead of the conjuncts sharing an expression on the right periphery, the pivot (shown in bold) is *internal* to the right conjunct (27).

(27) a. Bach [fetched] and [gave **the oboe** to Telemann].

b. Bach [edited] and [sent **the scores** out].

From the category of *and*, $(X/_L X)/_R X$, we know that in order for coordination to be licensed, the two conjuncts must be the same category. So (27a) is licensed if there is some way to give the conjuncts *fetch* and *give to Telemann* the same category. Indeed there is, if both verbs undergo **I** and become discontinuous. When it comes time for the left conjunct to combine with right conjunct and the conjunction, there are two discontinuous strings concatenating. Recalling the convention from Section 4.2 only the functor expression, i.e. the right conjunct, is allowed to keep its infixation point (condition 3). Otherwise, the resulting expression would have two infixation points, and *wrap* would be undefined.

(28)



There are, however, cases of RNW that the present discontinuous CCG cannot account for without some additional explanation. In (29), the discontinuous constituent is a transitive verb and an adjunct. Since the adjunct is not subcategorized for by the verb, normally these expressions would not form a discontinuous constituent.

(29) Bach [composed] and [performed **the prelude** eight times].

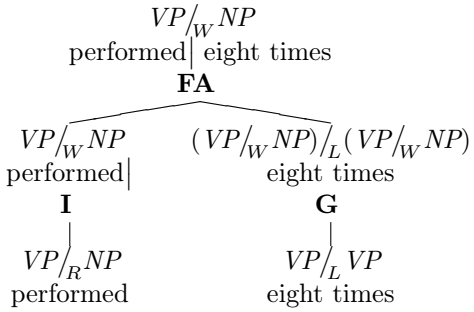
As in section 3, such non-canonical constituents can be generated with the combinatory rules **L** and **G**. These rules have to be generalized, however, so that they can apply to discontinuous $/_W$ and $/_I$ (30-31). The essential insight in formalizing these rules is that word-order preservation is definitional to them. The new definitions, then, license any **L** or **G** that does not alter word order.

(30) **L**: $A \Rightarrow B/_I(B/_W A)$ $\qquad$ $A \Rightarrow B/_W(B/_I A)$

(31) **G**: $A/_i B \Rightarrow (A/_j C)/_k(B/_l C)$
with j, k, l such that the result of **FA** $(A/_i B)$(**FA** $(B/_l C)$(C)) is the same as the result of **FA** (**FA** $((A/_j B)(B/_l C))$(C)

So the discontinuous constituent *performed*| *eight times* can be gotten (32).

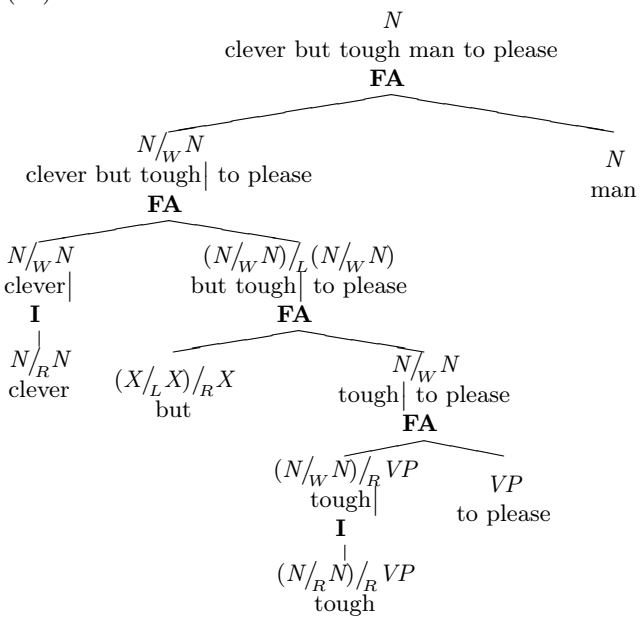
(32)



Additional RNW data that the current system does not generate are cases in which tough-adjectives form discontinuous constituents (33). Of course, the tough construction is independently supposed to be discontinuous (e.g. Dowty 1997). We may suppose then that **I** also applies to all prenominal adjectives, allowing *clever*| to take its argument by vacuous *wrap*, and coordinate as a like-category expression with *tough*| *to please* (34).

(33) Bach is a [clever] but [tough **man** to please].

(34)



5.1 Other Accounts of RNW

It is worth mentioning that the phenomenon of RNW has been treated in other grammatical frameworks. The first account comes from Whitman (2009), who uses a Multimodal Type-Logical Grammar. This framework, though related to CCG, allows rules that require knowledge of the structure of the strings

they license. Whitman's account makes essential use of structural rules which permute constituents, simulating movement. Recall that CCG only needs to "remember" the string, not a more complicated structure like a tree. To be fair, the discontinuous CCG does demand that the grammar "remember" the location of the infixation point, but this is considerably less information than a tree.

Another account of RNW comes from Chaves (2014) in the HPSG framework. Chaves argues that RNW is outside the purview of syntax, and is actually a morphophonological deletion process. The account uses HPSG's linearization feature to delete identical morphemes found in the syntax of both the conjuncts. This account has the same problems as deletion or ellipsis accounts of RNR discussed in section 3: it fails to predict that the shared expression in RNW can obtain wide scope over disjunction (35).

(35) *Context: A group of Bach fanatics wants to censor all music that is not by Bach, so they visit music libraries destroying all non-Bach scores.*
Either Bach composed or fanatics destroyed [every score in the library] at the book-burning. ($\forall \succ \vee$)

Additionally, Chaves's account requires an additional apparatus outside of the syntax to account for RNW. The addition of the linearization feature means that the string that is pronounced is not the result of the syntax. By contrast, the result of CCG syntactic derivations is pronounceable strings: the syntax does not need to be abstracted away from with mechanisms that simulate transformations.

6 Conclusion

The discontinuous CCG defined in sections 4 and 5 amounts to an overhaul of the traditional notion of constituency on two counts. First, the combinatory rules **L** and **G** together allow any word-order preserving string to be a constituent. Second, constituents may be discontinuous in the resulting string. The phenomenon of RNW provides good evidence that both these mechanisms are necessary, since constituents which are both non-canonical and discontinuous can coordinate.

At first blush this account of RNW may seem to risk excessive generative power with its extended notion of constituency. The truth, however, is quite the contrary. These few mechanisms allow the grammar to be quite weak while retaining empirical adequacy. The syntax is able to remain entirely monostratal — no transformations or additional "levels of representation" are required to generate complicated strings. In fact, the syntax need only build strings and must keep track of no internal structure in these strings aside from the location of a single infixation at most for each expression.

This paper adds to the wide range of phenomena that can be described in a CCG. Indeed, it supports the more general hypothesis that the most elegant and simple architecture for an adequate grammar of natural language is directly compositional and monostratal.

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