Syntactic Affixation and Performance Structures

Steven Abney

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1 Introduction

Functional elements (determiners, complementizers, modals, degree words) are in many ways the syntactic analogues of affixes in morphology. Typically, functional elements are bound elements. Phonologically, they are clitics: syntactically, they are unable to appear without an associated thematic element (noun, verb, adjective). I would like to extend the analogy by showing that functional elements also combine with their associated thematic elements to form word-like units I call *chunks*. For example, the segment of a noun phrase from the determiner to the head noun is a chunk. *The ongoing destruction of documents,* for instance, consists of two chunks, *the ongoing destruction* and *of documents.*

Chunks resemble words on several counts. Like the morphemes that form words, the words that form chunks are relatively tightly bound together. They generally cannot be moved out of their chunk, and the order in which they occur within the chunk is fixed. For example, the determiners, quantifiers, numerals, adjectives, etc. that constitute a noun chunk cannot be extracted, and are subject to elaborate and fairly rigid ordering constraints.

Further, in the same way that inflected forms cannot be embedded within words (e.g. **dogscatcher*), chunks containing functional elements cannot be embedded within other chunks. I discuss this constraint in detail in later sections. It accounts for a wide range of data, including the prohibition against complements in prenominal AP's. **A proud of his son man* is ill-formed because the chunk *of his son* is embedded in the chunk *a proud man.*

Chunks are not constituents of S-structure. *The ongoing destruction,* for instance, is not a constiuent of *the ongoing destruction of documents.* Rather, chunks constitute a level of representation that mediates between S-structure and a number of aspects of performance, such as intonation. In the next section, I would like to discuss the role of chunks in linguistic performance. Subsequently, I turn to evidence that chunks are not only elements of a performance representation, but genuine syntactic elements, as well.

2 Performance Structures

2.1 Performance Structures and Φ-Phrases

Regarded as substrings of a sentence, chunks differ only in minor respects from the *φ-phrases* of Gee and Grosjean 1983. Gee and Grosjean consider a number of experiments probing such diverse aspects of linguistic performance as intonation, the distribution of pauses in sentences read aloud, and the units identified by linguistically naive subjects as the constituents of sentences. They show that there is a natural projection of structure from the data thus acquired, and that the resulting *performance structures* can be predicted with considerable accuracy from *φ-phrases,* a particular kind of word cluster derived from the phonological phrases of Selkirk 1984 and others.

An example of a performance structure is the following (taken from Gee and Grosjean 1983, figure 1):

(1)
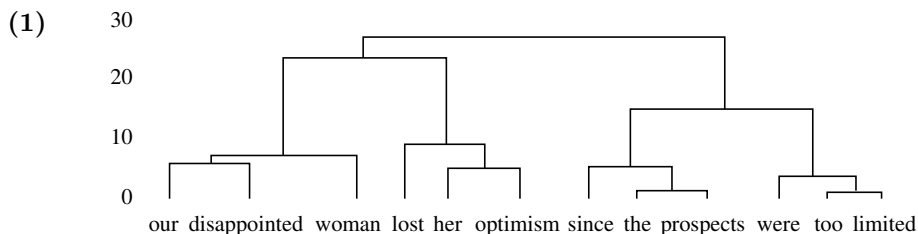
A number of subjects were asked to read the sentence at several different reading rates. Mean pause durations between adjacent words were calculated. They are expressed in (1) as a percentage of the sum of the means for each adjacent-word pair. (The numbers add up to 100.) Projecting these numbers onto the scale marked at the left yields the tree shown.

One striking aspect of performance structures is the clustering of words into fairly tight units with much larger pauses between. Gee and Grosjean claim that the frequency distribution of percent pause duration values shows a marked drop at about 7%. Their algorithm for predicting performance structures accounts for this clustering via the construct φ-phrase.

Paraphrasing Gee and Grosjean, a φ-phrase is defined as a substring of the surface string beginning immediately after a content-word head (or the beginning of the surface string), and ending immediately after the next following content-word head. By Gee and Grosjean's assumptions, *woman, optimism, prospects,* and *limited* are the only content-word heads in (1); accordingly, the φ-phrases are as marked in (2):

(2) [Our disappointed woman] [lost her optimism] [since the prospects] [were too limited]

In broad outline, the Gee and Grosjean algorithm proceeds in two steps. First, it builds φ-phrases, and assigns values to word boundaries within φ-

phrases, increasing from right to left. Then it builds "I-phrases" (intonation phrases) from the ϕ-phrases, and assigns values to inter-ϕ-phrase word boundaries according to the complexity of the minimal I-phrase that contains them. A prediction of the algorithm is that inter-ϕ-phrase boundaries generally represent significantly greater breaks than intra-ϕ-phrase boundaries. That prediction appears to be empirically correct. In (1), for example, intra-ϕ-phrase boundaries have (empirical) values of 8 or less, while inter-ϕ-phrase boundaries have values 24, 28, 15. Gee and Grosjean claim that their algorithm predicts values which correspond to empirically-determined values with a correlation of .96.

2.2 Φ-Phrases and Chunks

Despite the value of ϕ-phrases for predicting performance structures, certain aspects of Gee and Grosjean's account are disturbing from a syntactic point of view. First, their concept of syntactic headship is too narrow. For example, they must assume that prenominal adjectives are not syntactic heads, else they would incorrectly predict ϕ-phrase boundaries after each prenominal adjective. It is clear, however, that prenominal adjectives head full adjective phrases; consider e.g. *a [virtually defunct and almost completely useless] radio*. Second, Gee and Grosjean do not assign syntactic structure to ϕ-phrases. They do assign structure to ϕ-phrases, but it is uniformly right-branching, and is employed only as a mechanism for enumerating word boundaries from right to left.

By contrast, I shall define chunks in terms of a function word and the content word (thematic element) it selects. Prenominal adjectives are thematic elements and heads, but they are distinguished from thematic elements like nouns and verbs in that they are not selected by functional elements. In addition, chunks are assigned syntactic structures, which are subgraphs of the structure assigned to the sentence as a whole.

To define *chunk* more formally, we require some auxiliary definitions. Drawing on Abney 1987, we first define two types of syntactic projection, *c-projection* and *s-projection* (see example 3).

(3)   a.   b.
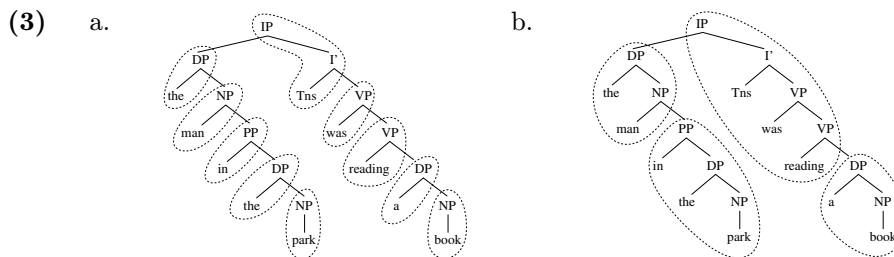
C-projection ('category' projection) is based on simple syntactic headship. S-projection ('semantic' projection) is based on notional headship, and captures the intuition that the verb is the head of the sentence (IP), the noun is the head of the noun phrase (DP), etc.

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(4) α is a c-projection of β iff

    (i) $\alpha = \beta$, or

    (ii) the immediate head of α is a c-projection of β

    α is an s-projection of β iff

    (i) $\alpha = \beta$, or

    (ii) the immediate head of α is an s-projection of β, or

    (iii) α f-selects an s-projection of β.

Concisely, c-projection is the reflexive-transitive closure of immediate-headship^{-1}, and s-projection is the reflexive-transitive closure of immediate-headship$^{-1} \cup$ f-selection^{-1}.

    Chunks are very similar to the tree-segments marked in (3b) as s-projection paths. Let us call the topmost node in a relevant s-projection path a *chunk-ceiling*:
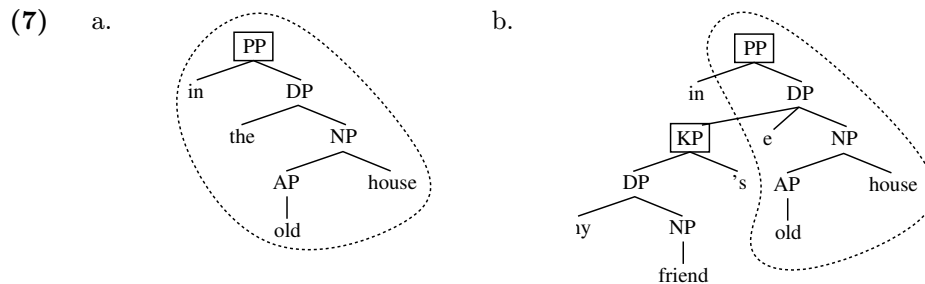
(5) a *chunk-ceiling* is the maximal s-projection of a thematic element selected by a functional element

Chunk-ceilings are the boxed nodes in (7). We restrict chunk-ceilings to s-projections of thematic elements selected by functional elements to prevent e.g. prenominal adjectives from defining separate chunks.

    Now we define chunks in terms of chunk-ceilings:

(6) a *chunk* is the maximal subgraph of a chunk-ceiling C which:

    (i) includes the thematic element defining C

    (ii) does not contain any other chunk-ceiling, and

    (iii) has a connected frontier

The following structures illustrate (intermediate bar-level nodes omitted for brevity's sake):

(7)   a.   b.

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The boxed nodes are chunk ceilings; the circled tree-segments are chunks. In (7a), *the* selects the thematic element *house* and the maximal s-projection of *house* is PP; hence PP is a chunk-ceiling. In (7b), there are two function words selecting (phrases headed by) thematic elements: *my* and the empty determiner *e*. *My* selects *friend,* and the maximal s-projection of *friend* is KP (Case-marker Phrase). *e* selects *house,* and the maximal s-projection of *house* is PP. In (7a), the maximal subgraph of PP which includes *house,* does not include another chunk-ceiling, and has a connected frontier, is the entire structure; hence the entire structure describes a single chunk. In (7b), the chunk defined by PP is circled. *In* would be included in the maximal subgraph of PP which does not contain another chunk ceiling, but the inclusion of *in* in the chunk would give it the disconnected frontier *in e old house.*

Applying the definition of *chunk* to example (2) yields chunks as marked:

(8)   [Our disappointed woman] [lost] [her optimism] since [the prospects] [were too limited]

As segments of the surface string, these phrases differ from ϕ-phrases only in containing 'orphaned' words which belong to no chunk, such as *since.* We can map chunks to ϕ-phrases simply by sweeping orphaned words into the following chunk.

2.3   Chunks in Parsing

Even though chunks are not constituents, they can readily be assembled into a complete phrase structure tree by *attachment*—that is, by adding the missing branches between chunks. For example, to construct the phrase *the man in the park,* we add a branch from the NP node *the man* to the root node of *in the park.* Thus it is straightforward to combine a *chunker,* which builds the internal structure of chunks, with an *attacher,* which assembles chunks into a complete parse tree.

Some of the advantages that accrue to such a parser are the following. First, the correspondence between chunks and prosody (via ϕ-phrases) makes a chunker of porential use for speech synthesis. Second, even ill-formed sentences and sentences involving unknown constructions generally consist of well-formed chunks. Hence, a chunking parser can recover useful information even from sentences which it cannot completely parse.

But most importantly, the problem of constructing chunks and the problem of assembling chunks into complete trees differ significantly. For example, attachment ambiguities, which present an especially difficult problem for parsing, arise only between chunks, not within chunks. Hence, a division of labor between a chunker and attacher is appropriate. The chunker simplifies the task of the attacher by resolving certain issues, such as lexical ambiguity, on its own, and by reducing the number of elements the attacher must deal with. (For further discussion of these matters, see Abney, forthcoming.)

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3 Chunks in Syntactic Explanation

3.1 In the Noun Phrase

It should be clear that chunks represent a constituency analysis that differs systematically from standard phrase structures. Chunks sometimes circumscribe rather odd pieces of the phrase-structure tree. However, chunks do not replace standard constituents, but rather supplement them. We have briefly considered how chunks contribute to an explanation of performance. In the remainder of the paper, I would like to discuss the role they play in syntactic explanation.

In particular, let us consider the following constraint:

(9)   *Chunk Connectedness*
A functional element defining a chunk must be included in the chunk it defines.

The examples given above, in (7), observe Chunk Connectedness. Each chunk is defined by a D–N pair, and both D and N are included in the chunk they define. Let us consider some examples which do not obey Chunk Connectedness:

(10)   **a.**   *the proud [of his son] [man]

       b.   *an eager [to please] [man]

       c.   *a sinking [in the ocean] [ship]

In (10a), for example, *the* selects *man,* defining the chunk-ceiling DP. *The* cannot be included in the same chunk with *man,* because the PP *of his son* intervenes. We are forced to orphan both *the* and *proud.* The failure to include *the* in the chunk it defines violates Chunk Connectedness. Similarly for the other examples.

We can express Chunk Connectedness another way, which is perhaps more intuitive. Every chunk C is defined by a function word f and a thematic element θ. Define the *required frontier* of C to be the string beginning at f and ending at θ. The required frontier of C fails to be a substring of the actual frontier of C only if f is an orphan, which occurs only if some chunk intervenes between f and θ. Conversely, if some chunk intervenes between f and θ, then f is orphaned, and the required frontier of C is not a substring of its actual frontier. Therefore, (9) is equivalent to (11):

(11)   No chunk may be embedded in the required frontier of another chunk

For example, (10a) is ill-formed because the chunk *of his son* is embedded in the required frontier of the larger chunk: *[the proud [of his son] man].*

Note that Chunk Connectedness does not apply at D-structure. Prenominal adjective phrases *can* take complements, provided that those complements are

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extraposed around the noun: *an easy man to please.* Significantly, extraposing the complement around the noun is the minimal displacement necessary to satisfy Chunk Connectedness. Whereas *[an easy [to please] man]* involves the embedding of one chunk within the required frontier of another, *[an easy man] [to please]* does not. In a similar vein, the examples of (10) are good if the adjective phrases are postnominal, rather than prenominal: *OK [the man] [proud of his son], OK [a man] [eager to please], OK [a ship] [sinking in the ocean].*

It is an old observation that prenominal modifiers may not contain complements. For example, Edmonds 1976 formulates a Surface Recursion Restriction that prohibits a pre-head constituent of category X from containing an S, a PP or another X. (It does not apply in head-final languages; nor does it apply to the immediate constituents of S, given Emonds' assumption that S is exocentric.) Also, Williams 1982 postulates a Head-Final Filter prohibiting post-head material within prenominal modifiers. However, Chunk Connectedness is more general than a prohibition against post-head constituents within prenominal modifiers. It is also violated by e.g. measure phrases containing functional elements, in particular, determiners:

(12) *[the [a dozen] men]   OK [the dozen men]
    *[the [$\emptyset_{\text{Det}}$ thousands] men]   OK [those thousand men]
    *[a [$\emptyset_{\text{Det}}$ six feet] long board]   OK [a six foot long board]
    *[a [$\emptyset_{\text{Det}}$ six inches] diameter circle]   OK [a six inch diameter circle]

Following Jackendoff 1977, I take numerals and "semi-numerals," like *dozen, three,* etc., to be nouns heading NP's. I assume they can appear as bare NP's (i.e., not embedded in a DP) in the same position as prenominal AP's: *the dozen men, the three men.* If they *are* selected by D, a chunk is created, and they can no longer appear in prenominal position: **[the [a dozen] men], *[the [$\emptyset_{\text{Det}}$ thousands] men].*[1] I take nominal AGR (i.e., plurality), like verbal AGR, to be morphologically borne by the s-head (noun, verb), but syntactically realized by an empty functional element (D, I). Hence, the heads of bare NP's may not be morphologically marked for number, giving us the contrast **a six feet long board, OK a six foot long board.*

A word or two is in order about bare NP's. Under the DP analysis of Abney 1987, 'noun phrase' is actually DP; NP under the DP analysis corresponds to N-bar under the standard analysis, and appears *only* as complement to D. But if *six foot* is a bare NP in *a six foot long board,* then we can no longer assume that NP appears only as complement to D. However, NP does continue to be restricted in its distribution. For one thing, NP cannot be the root node of a chunk; NP can be a maximal s-projection only if it is not selected by any functional element, but in that case, there is no functional element–thematic

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[1] In *a dozen men, a thousand men,* the determiner clearly belongs with the semi-numeral, not with *men* (**a men*). I return to these examples below (see discussion after example 17), where I argue that the structure is in fact not *[$\emptyset_{\text{pl}}$ [a dozen] men]*, but *[a dozen] [$\emptyset_{\text{pl}}$ men]*.

element pair, hence no chunk. As a consequence, NP—every thematic category, for that matter—is a 'dependent morpheme,' under the chunk-as-syntactic-word metaphor. It cannot be a chunk itself, only a part of a chunk.

Actually, there is a third alternative: instead of being either a chunk, or a proper subpart of a chunk, the words in NP's frontier may belong to no chunk at all. That is, they are orphaned words. To preclude this alternative, I adopt the following condition:

> *Chunk Inclusiveness*
> With the exception of a distinguished subset of function words (the 'orphanable' words), every word must belong to some chunk

Chunk Inclusiveness guarantees that, at the level where chunks are represented, there is no unstructured material apart from certain designated function words.

Chunk Inclusiveness contributes to an account of the ill-formedness of the following examples:

(13)   **a.**   *[$\emptyset_{\text{Det-pl}}$ proud [of their sons] men]

        b.   *[$\emptyset_{\text{Det-mass}}$ filled [with PCBs] water]

If (13a) and (b) are chunks, they cannot be bare NP's (by the definition of chunk). There must be an empty determiner present, as indicated. Hence, they violate Chunk Connectedness. If they are not chunks themselves, then they are part of a larger chunk (by Chunk Inclusiveness), and the presence of *of their sons/with PCBs* causes a violation of Chunk Connectedness in that larger chunk.

Taking Deg to be a functional category, we can include the following examples in paradigm (12):

(14)   *[a [too hot] day]   OK [an extremely hot day]
         *[a [how big] house]   OK [how big] [a house]
         *[an [as big] house]   OK [as big] [a house]
         *[a [that big] house]   OK [that big] [a house]

Examples like [a [$\emptyset_{\text{-er}}$ bigger] man], [a [less intelligent] dog], [the [most beautiful] woman] apparently do not fall in this paradigm. I take this as evidence that *less, most,* etc. are not Deg's, but of the same category as their positive forms, *little, much,* i.e., Q. (Comparative and superlative are semantically degree relations, but that does not require that they be realized syntactically as Deg, any more than all semantic quantifiers are realized syntactically as Q—some are Det, some are Numerals, etc.)

3.2   In Adjective Phrase and Verb Phrase

Consider the following examples:

(15)   **a.**   *[$\emptyset_{\text{Deg}}$ less [than the red one] provocative]
OK [$\emptyset_{\text{Deg}}$ less provocative] [than the red one]

   b.   *[was [for three days] painting] (the house)
OK [was painting] [the house] [for three days]

   c.   *[has [three times] painted] (the house)

   d.   *[was [too aggressively] defending] (the goal)
OK [was aggressively defending] (the goal)

The empty Deg in (15a) is forced by the same considerations that required empty Det's in (13). Suppose there is no empty Deg. If [$_{\text{AP}}$ *less than the red one provocative*] is part of a larger chunk, as in *a less than the red one provocative dress*; then Chunk Connectedness is violated in the larger chunk. If the AP is part of no chunk at all, it violates Chunk Inclusiveness.

Note that *less [than the red one] provocative* contrasts with *OK [$\emptyset_{\text{Det}}$ six inches] long*.[2] We can account for the contrast by assuming that QPs (e.g., *less than the red one*) appear after the empty Deg, whereas measure phrases (*six inches*) appear before the empty Deg. Unfortunately, corroborative evidence with overt Degs appears impossible to find, because overt Degs are incompatible with QP's and measure phrases modifying the head adjective. That is, examples like *six inches too long* mean 'too long by six inches,' *not* 'too long, to wit, six inches long.' However, consider:

it was six inches in length
*it was less in length

This contrast is predictable under the assumption that *[$\emptyset_{\text{Deg}}$ long]* is syntactically a complement of sorts to *six inches* in *six inches long,* whereas *less* is a simple prehead modifier of *long (provocative)* in *less long (less provocative).*

Let us turn now to (15b–d). (15b) and (c) are straightforward: assuming the functional element–thematic element pair that defines the verb chunk is Infl–V, *for three days* and *three times* represent chunks within the required frontier of the verb chunk. (15d) shows that adverb phrases with Deg inside of verb chunks violate Chunk Connectedness, exactly as adjective phrases with Deg inside noun chunks do. Bare AdvP's do not cause a violation. In this connection, consider *was more than anyone else aggressively defending the goal.* Since, as we have just assumed, no Deg is required, there is not necessarily an empty Deg selecting *aggressively* to account for the violation in this case. However, even if no Deg occurs, *than anyone else* constitutes a chunk within the required frontier of the verb chunk (*Tns . . . defending*), and Chunk Connectedness is violated. Note

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[2] *less than the red one provocative* also contrasts with *OK more than a mile long.* I take the latter to have the structure [$_{\text{QP}}$ more than [$_{\text{MeasP}}$ a mile [$_{\text{DegP}}$ $\emptyset_{\text{Deg}}$ long]]], not [$_{\text{DegP}}$ $\emptyset_{\text{Deg}}$ [$_{\text{QP}}$ more than a mile] long]. Hence it patterns with *six inches long,* not with *less than the red one provocative.*

that in this case, extraposition of the *than*-phrase to the end of the adverb phrase does not help: **was more aggressively than anyone else defending the goal. Than anyone else* still appears within the required frontier *Tns ... defending.*[3]

4   Apparent and Actual Problems

An apparent problem for our analysis is presented by the following construction:

(16) $[\emptyset_{\text{Det}}$ [how small] [a gauge] wire] (do you need)
        $[\emptyset_{\text{Det}}$ [how small] [a diameter] circle] (can you draw)

Since the chunks *how small* and *a gauge (a diameter)* are bracketed by the function-word/content-word pair $\emptyset_{\text{Det}}$ *... wire (circle),* we expect the examples to be bad, but they are fine.

But consider simpler examples of the same construction, e.g. *how big a house (do you live in)?* In this case, it is clear that *how big* in fact precedes the determiner, presenting no problem for Chunk Connectedness. By extension, examples (16) should actually be analyzed:

(17)   [how small] [a gauge] $[\emptyset_{\text{Det}}$ wire]
        [how small] [a diameter] $[\emptyset_{\text{Det}}$ circle

A similar problem, with a similar solution, is raised by examples like $\emptyset_{\text{Det}}$ *a dozen men.* If we assume a structure for *a dozen men* parallel to that for *how small a gauge wire,* i.e., [a dozen] $[\emptyset_{\text{Det}}$ men], then Chunk Connectedness is not violated.

The analysis extends also to examples like *two parts gin,* i.e., [two parts] $[\emptyset_{\text{Det}}$ gin]. Note that in all three constructions, partitive-like alternatives with *of* also exist: *how small a gauge of wire, a dozen of the men, two parts of gin.* There are differences in the conditions under which *of* appears, but the parallelism is at least suggestive.

Conjunction presents another problem. If we adopt an analysis in which conjunctions are functional elements, and conjunction structures have the form $[_{\text{XP}} ... \text{X'} [_{\text{conjunct}} \text{conj XP}]]$, then conjunction of adjectives should yield a violation of Chunk Connectedness:

(18)   [a big [and black] dog]

The simplest solution appears to be to consider that conjunctions do not qualify as functional elements for the purposes of the definition of chunks. In fact, conjunctions differ from (other) functional elements on some key points. Functional elements have very specific selectional properties, whereas conjunctions appear

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[3] **was more aggressively defending than anyone else the goal* is bad because of a violation of Case adjacency, which I take to be an unrelated constraint.

with any category at all. Also, functional elements uniformly take some kind of specifier—be it a subject (in IP, CP, DP) or a measure phrase (in PP)—whereas conjunctions take no specifier at all. Thus, it is reasonable to suppose that the classes *functional element* and *thematic element* do not partition the syntactic categories, but that at least conjunctions belong to neither class. Hence, we predict no violation in (18), but we (correctly) predict a violation in examples like the following:

> *[an exiled, but fiercely proud [of his heritage], Hungarian aristocrat]
> (vs. OK [an exiled, but fiercely proud, Hungarian aristocrat])

Finally, there is at least one apparent violation of Chunk Connectedness for which I have no good account. Consider:

(19) **a.** *an as devastating attack

  b. ?a nearly as devastating attack

(19b) indicates that Chunk Connectedness is not completely inviolable.

Part of the contrast is possibly due to a surface constraint against immediately adjacent Deg's and Det's, but I also find a contrast in the following pairs, where that is not a factor:

(20) **a.** *a much too heavy belle dame
    ?a much too heavily made-up belle dame

  b. *a six microns thick lens
    ??a six microns too thickly coated lens

I leave this as an open question.

5 Conclusion

In sum, I have shown that a range of hitherto recalcitrant data can be accounted for by a single constraint, Chunk Connectedness. This predictive ability indicates that chunks are genuine syntactic constituents. Chunks are not S-structure constituents, but rather constitute a level of representation derived from S-structure that mediates intonation and other aspects of linguistic performance.

Chunk Connectedness is not a universal constraint; it does not hold in German, for instance.[4] Alternatively, we might speculate that German lacks chunks,

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[4]For example, *die auf der Rückseite beschriebene Aufgabe* (literally, 'the on the reverse side described assignment') is perfectly grammatical. Here, something like Emonds' and Williams' prohibition against posthead material in prenominal modifiers might appear to make better predictions. That is, **die beschriebene auf der Rückseite Aufgabe* is ungrammatical. However, such examples are ungrammatical because German is head-final generally; material may appear after the head only under restricted conditions. Compare OK *die Aufgabe wird auf der Rückseite beschrieben; ?*die Aufgabe wird beschrieben auf der Rückseite.*

rather than Chunk Connectedness. Conceivably, chunks fill a gap left by an impoverished morphology, providing polymorphemic word-like units in languages with scant inflection or agglutination. However that may turn out, the cross-linguistic characterization of chunks is an important issue for future research.

Finally, chunks are defined in terms of functional elements and f-selection; hence, evidence that chunks play a causal role in the syntax provides indirect support for our characterization of functional elements and the structures they project.

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