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Feature Bundles, Prenominal Modifier Order, and Modes of Composition Below the Word Level

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1 Introduction

Contemporary syntactic theory places much explanatory weight on the notion that certain features are interpretable (at an interface) and others are not. Whether what 'interpretable' means in this sense can be identified with what is meant by the word in its formal semantic sense is not obvious, and it certainly isn't a logical necessity (as Potts 2004 among others has pointed out). The strongest and most interesting hypothesis, though, is that these are in fact the same notion.[1] Among the hurdles that will have to be jumped in order to maintain this view is the question of how features should be interpreted when bundled together. The usual mechanisms that perform semantic composition (such as those in Heim and Kratzer 1997) are defined to apply to distinct nodes, so if a single node contains more than one interpretable feature—in the syntactic and semantic sense, by hypothesis the same—these mechanisms could not assemble the denotations of these features. Or, to put it another way, any node containing more than one interpretable feature would be semantically uninterpretable. The aim of this paper is to remedy this situation by elaborating the semantics so that such feature bundles can be assigned an interpretation. This will touch on larger issues about the interpretation of functional heads and about sublexical semantic composition more generally.

People get thanked here...

[1] At least with respect to LF. PF interpretability would, of course, have to be a different animal.

The core of the proposal is that the principles of semantic composition that apply in feature bundles (and below the word level more generally, perhaps) are more flexible and in a sense less type-theoretically demanding than those that apply elsewhere. More precisely, I will propose extending the notion that function composition (not merely functional application) is available in the morphology—which is not new—to feature bundles, in a modified form. To implement this adequately, it will be necessary to borrow a basic combinatorial mechanism of Variable Free Semantics (Jacobson 1999 and others) and categorial grammar—the Geach rule—though in a much more restricted structural domain. The virtue of doing things this way is that it allows features of syntactic functional structure to have an accordion-like[2] property, in which precisely the same feature with precisely the same denotation can be interpretable—and make precisely the same contribution to the semantics of the expression—either in a functional head of its own, when bundled with other features, and even on a lexical head. Loosening up the semantics in this way permits more flexibility in positing syntactic structures, and in particular, this sort of bundling makes possible more representationally conservative (i.e., smaller) phrase structures where they are desirable without precluding more articulated ones where they are called for.

The empirical context in which this idea will be developed and illustrated will be English prenominal modification, more specifically certain facts about the relative order of classificatory adjectives, color adjectives, and attributive nouns of a particular sort. This is a domain in which there are correlations between the position and interpretation of a modifier that do not follow in any obvious way from independent semantic or semantic assumptions, and perhaps the only understanding of these facts otherwise available under current assumptions would be one in roughly the Cinquean spirit (Cinque 1994, 1999), in which functional projections which in this case have no other motivation must be posited. On the assumptions about feature bundling proposed here, though, more minimal structures can suffice.

Section 2 presents the poorly-understood and little-noted facts about English prenominal modification that will provide the empirical foundation here. Section 3 lays out the proposal, illustrating the theoretical advantages, in terms of phrase structural flexibility, of feature bundling with respect to these facts, and indeed more broadly. Section 4 concludes.

[2] Or telescope-like... or perhaps even like a fold-out sofa.

2 Some Puzzles About English Prenominal Modification

While there are some more familiar places which might have served as the empirical terrain here, I will focus instead on a more unfamiliar area, both because of its inherent interest and because it is one especially congenial to laying out the present proposal: the relative order of classificatory adjectives, color adjectives, and attributive[3] nouns. In this section I'll propose an account of this that relies on semantically-interpreted features, and, partly because of semantic considerations, must posit several functional projections. In subsequent sections I'll show how this result can be avoided by committing to some assumptions about feature bundle interpretation.

2.1 *Classificatory Adjectives*

Among the adjectives restricted to especially low positions are so-called 'classificatory' or 'relational' adjectives such as *musical* in *musical comedy* (Bosque and Picallo 1996, McNally and Boleda Torrent 2003, Cinque 2003, and references cited there). Obligatorily, these occur closer to the noun than adjectives of a number of other classes, including evaluative adjectives as in (1), size adjectives as in (2), and, most relevant at the moment, color adjectives as in (3–4):

(1) a. an awful *pulmonary* disease
b. *a *pulmonary* awful disease

(2) a. a huge *political* problem
b. *a *political* huge problem

(3) a. a beige *dental* instrument
b. *a *dental* beige instrument

(4) These horrible invitations are bad enough, but for god's sake, did they really have to print them on...
a. ...pink *nuptial* stationary?
b. *...*nuptial* pink stationary?

This fixed syntactic position correlates with a particular interpretation—it is exactly this fact that permits the use of (quasi-)semantic characterizations such as 'classificatory' to identify this class. Before proceeding further with this puzzle, it will help to introduce the others.

[3] By this I mean just 'nouns that occur prenominally'; I adopt the less transparent, more traditional term here because 'prenominal nouns' has a vaguely paradoxical flavor.

2.2 *Composition Nouns*

There is a distinct class of attributive nouns that designate the material of which something is composed. These include *leather* in *leather shoes* and *plastic* in *plastic box*. They have been referred to simply as adjectives (in e.g. Kamp and Partee 1995, who call *stone* in *stone lion* an adjective), but this can suffice only as a pretheoretical characterization—these expressions fail standard tests of adjectivehood, including ability to occur in comparatives or the complement position of *seem*:

(5) a. That hat is $\left\{\begin{matrix}\text{more}\\\text{very}\end{matrix}\right\}$ $\left\{\begin{matrix}\text{*metal}\\\text{metallic}\\\text{*leather}\\\text{leathery}\end{matrix}\right\}$.

b. That hat seemed $\left\{\begin{matrix}\text{*metal}\\\text{metallic}\\\text{*leather}\\\text{leathery}\end{matrix}\right\}$.

True adjectives such as *leathery* and *metallic* are perfectly grammatical in these contexts, but their nominal counterparts are clearly not, despite their semantic similarity.

Importantly, though, these are not simply members of noun-noun compounds, either.[4] Unlike nouns in compounds, composition nouns can be excluded in *one* pronominalization:

(6) a. *Floyd bought the coffee maker, and I bought the bread one.
b. Floyd bought the metal coffee maker, and I bought the plastic one.

(7) a. *Greta is wearing gym pants, and Herman is wearing sweat ones.
b. Greta is wearing spandex pants, and Herman is wearing leather ones.

So (7a) is ungrammatical because *sweat pants* (like *gym pants*) is a noun-noun compound, and *ones* cannot stand in for something that's a proper part of a compound. In (7b), on the other hand, *leather ones* is fine because *leather pants* is not a noun-noun compound. That these are not parts of

[4] This is not, of course, to say that composition nouns can't be lexicalized in particular cases, such as *paper bag*. They can, but of course so can adjectives (e.g. *old maid*) and members of virtually any other syntactic category (at least in idioms), so this is not evidence that composition nouns are *always* members of a noun-noun compound.

compounds is also reflected in their position. Composition nouns can occur only outside of a noun-noun compound. Thus a coffee maker made of steel can be characterized as in (8a), but not as in (8b); and similarly for the *pants* example in (9):

(8) a. steel coffee maker
b. *coffee steel maker

(9) a. leather gym pants
b. *gym leather pants

Maybe the most important evidence for not treating composition nouns as part of noun-noun compounds is that their semantic contribution is non-idiosyncratic, as the contribution of nouns in noun-noun compounds may be. To my knowledge, *mouse hat* is not an existing noun-noun compound in English. Accordingly, it has no fixed meaning—perhaps a *mouse hat* is a hat designed to be worn by mice, or perhaps it's a hat with big mouse ears on it (like a *Mickey Mouse hat*), or perhaps its a hat one wears to repel mice (cf. *mosquito net*). But in *steel mouse hat*, we can be quite sure what the contribution of *steel* is. Irrespective of what *mouse hat* means, *steel mouse hat* can be used to characterize an instance of something in the extension of *mouse hat* that also happens to be made of steel. It is of course also perfectly possible to lexicalize *steel mouse hat* (particularly on the parse not relevant here, *[steel mouse] hat*), but this would not eliminate the possibility of interpreting *steel* as a composition noun. And certainly, one might call a metallic hat worn by mice a *steel mouse hat* and not a **mouse steel hat*. So, to indulge in the inevitable pun, composition nouns are compositional.

One striking bit of evidence that composition nouns are not simply members of noun-noun compounds is relevant to the broader point here—they obligatorily occur above classificatory adjectives:

(10) a. a steel dental instrument
b. *a dental steel instrument

(11) a. a leather bridal gown
b. *a bridal leather gown

(12) a. a stone religious relic
b. *a religious stone relic

So again, since composition nouns can occur outside of classificatory adjectives, they cannot be simply members of compounds.[5] It also reflects that these composition nouns occupy a relatively fixed position. This position is below the one most naturally occupied by color adjectives:[6]

(13) a. a blue cotton shirt
b. *?a cotton blue shirt

(14) a. a yellowish metal shelf
b. *?a metal yellowish shelf

(15) a. a grey stone lion
b. *?a stone grey lion

The generalization, then, is that composition nouns are independent modifiers with their own syntactic distribution, one which places them systematically above classificatory adjectives and below color adjectives.

2.3 *Color Adjectives*

The final part of the empirical picture to be drawn is color adjectives. As we have already seen, color adjectives occupy a relatively fixed position in the DP. In addition to occurring obligatorily before composition nouns and classificatory adjectives, they are also restricted to positions below evaluative and size adjectives:

(16) a. the big red ball
b. *the red big ball

(17) a. the beautiful red ball
b. *the red beautiful ball

This is a more familiar puzzle than the previous two (it comes up in discussions of adjective position such as **?**, **?**, **?**, **?**, Cinque 1994, **?** among others, and work in the typological tradition such as **?** and **?**), but it remains one which for which a satisfying explanation is elusive. The only one available

[5] Unless, of course, one were to treat all classificatory adjectives as themselves part of a single complex lexical item. This, though, would be profoundly unsatisfying in several respects, chief among them that the semantics of classificatory adjectives is completely compositional.

[6] Some of these judgments are not perfectly clear-cut. One likely reason for this is that it's possible in principle (though not easy) to assign color adjectives classificatory adjective interpretations, so if a *yellowish shelf* can be construed as a particular variety of shelf, *metal yellowish shelf* will be fine for precisely the same reason e.g. *steel dental instrument* in (10) is.

that I am aware of is in the (broadly) Cinquean tradition, in which color adjectives occupy a particular position in the hierarchy of functional heads. Cinque (1994) places them in the specifier position of a ColorP, whose position is fixed with respect to corresponding projections for evaluative and size adjectives. This, though, leaves the semantics curiously out of the picture, in much the same way the Cinquean approach to adverbial modification (Cinque 1999) does. It treats 'color adjective' as merely a lexical class, whose membership could just as well have been utterly unpredictable and idiosyncratic—but of course, it is not. Any adjective that has the appropriate meaning acts in precisely this way, exceptionlessly. So some explanation is required for why this particular position should correlate with a color interpretation.

2.4 *Assembling the Pieces: An Initial Account*

Importantly, the facts here do not appear to follow in any straightforward way from independently motivated syntactic assumptions, or from any independently motivated semantic ones. It is not plausible, for example, to suppose that color adjectives must occupy a particular structural position because they must modify an object of a sort that is available only in exactly that position, since this would require that the sorts of things of which a color adjective can be predicated should be fundamentally ontologically different from ones of which an evaluative adjective denotation can be predicated, or for that matter a size adjective.

Thus the analytical strategy I will adopt will be to factor out bits of apparently lexical meaning from the modifiers, and to attribute them instead to licensing features of which the modifiers are arguments. This essentially amounts, in some somewhat abstract sense, to giving a denotation to the position of the modifier itself.

For classificatory adjectives, this crucial feature—[+CLASS], say—can be assigned a semantics roughly along the lines proposed by McNally and Boleda Torrent (2003). They suggest that classificatory adjectives are introduced by a special rule of semantic composition that predicates the adjective of a kind, and yields a property of realizations of that kind as the denotation of the modified NP.[7] Thus [+CLASS] can do the work this rule

[7] More precisely, the realization relation itself is not provided by the rule, but independently by the semantics of every noun that occurs with a classificatory adjective. It doesn't seem to me to do any harm to the semantics they propose or to the analysis of these structures more generally to extract the realization relation from the noun's semantics in this way. They also propose that the kind is contextually-provided rather than bound by an existential quantifier as it is in (18)—I take this route here for simplicity of exposition, but it does

would otherwise have to:

(18) $[\![\,[\text{+CLASS}]\,]\!] = \lambda P_{\langle e,t\rangle}\ \lambda A_{\langle e,t\rangle}\ \lambda x\,.\,\exists k[A(k) \wedge P(x) \wedge x \text{ realizes } k]$

This will take as arguments an NP denotation and a classificatory adjective denotation (here construed following McNally and Boleda Torrent 2003 as a property of kinds), and yield a property of individuals that realize a kind that satisfies the denotations of both the adjective and the head noun.

For composition nouns, for current purposes it will suffice to assume a feature [+COMPOSITION] with a semantics that contributes a material 'composed of' relation that won't be examined further here:

(19) $[\![\,[\text{+COMPOSITION}]\,]\!] = \lambda P_{\langle e,t\rangle}\ \lambda C_{\langle e,t\rangle}\ \lambda x\,.\,P(x) \wedge \exists y[C(y) \wedge x \text{ is composed of } y]$

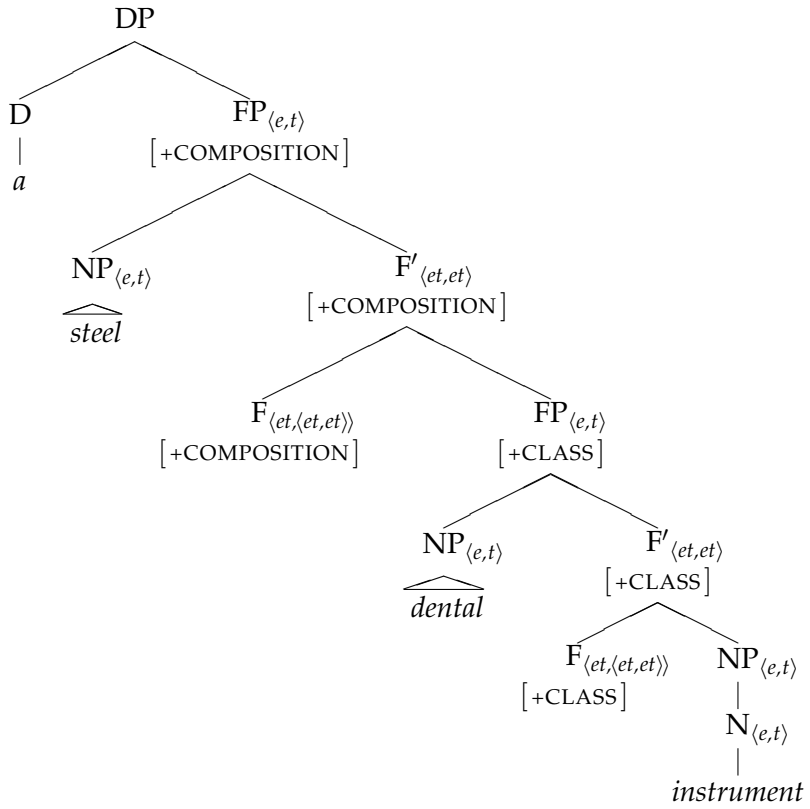
This will take as arguments the denotations of the NP and the composition noun, and yield a property of individuals which are composed from something that satisfies the composition noun denotation.

With this in place, *a steel dental instrument* can be assigned the structure in (20)—following Cinque (1994) in placing the adjective in a specifier position—and the denotation in (21):[8]

not strike me as obviously wrong.

[8] I use k,k′,... as variables that range over kinds, and will not indicate the distinction between kinds and ordinary individuals in any other way. I take kinds here to be of type *e* just like ordinary individuals.

(20)



(21) a. ⟦ *instrument* ⟧ = λx . instrument(x)
b. ⟦ *dental* ⟧ = λk . dental(k)
c. ⟦ *dental* [+CLASS] *instrument* ⟧
= ⟦ [+CLASS] ⟧(⟦ *instrument* ⟧)(⟦ *dental* ⟧)
= λx . ∃k[dental(k) ∧ instrument(x) ∧ x realizes k]
d. ⟦ *steel* ⟧ = λy . steel(y)
e. ⟦ *steel* [+COMPOSITION] *dental* [+CLASS] *instrument* ⟧
= ⟦ [+COMPOSITION] ⟧(⟦ *dental* [+CLASS] *instrument* ⟧)(⟦ *steel* ⟧)
= λx . ∃k[dental(k) ∧ instrument(x) ∧ x realizes k] ∧ ∃y[steel(y) ∧ x is composed of y]

At the cost of the stipulation of the relative order of these features, then, this accounts for the (otherwise unexplained) facts about why composition noun and classificatory adjective interpretations should be restricted to particular positions in this way—and it explains how these interpretations arise in the first place.

But what about color adjectives? If the approach so far can be taken here, too, it will be necessary to distill some component of the apparent

lexical semantics of color adjectives and to attribute it to a feature of which the modifier can be an argument. So for color adjectives, the natural thing to suppose is that the position they occupy is simply associated with the semantics of color. But the next step this would lead to is more than a little awkward—it's not clear how one could factor out the meaning associated with color from *red* or *blue* without losing the very heart of what these adjectives mean. One could, perhaps, suppose that the lexical semantics of *red* doesn't really (in some tortured sense of 'really') directly say anything about having a color, but *red* happens to be true only of things that have a red color (perhaps for some reason having to do with nonlinguistic facts about the world). This, though, seems to be slicing things a bit too thin.

An alternative would be to suppose that *red* means exactly what one might think it does, and that the (prenominal) position it occupies has a semantics associated with a 'x is of the color y' relation. This, in other words, doesn't factor out the color meaning so much as mirror it. This would do the trick—it would enforce the association between that position and color semantics as a kind of selectional restriction, essentially by ensuring that only color adjectives could be interpreted there because only they are compatible with the color semantics required of an adjective that occurs there. But while this is all perfectly compatible with what has been considered so far, it isn't very satisfying, either. If the essential idea here is that positions can have meanings, evidence for this idea will have to come from instances where positions have meanings that are independently detectable, not ones that simply mirror the independent lexical semantics of a modifier. To find real evidence for this approach from color adjectives, then, it will be necessary to find some independent meaning associated with the prenominal color adjective position that can be disentangled from the lexical semantics of color adjectives themselves.

Led to look for it in this way, we indeed find it. There are aspects of the interpretation of color adjectives that are particular to their prenominal position—that is, that are found there systematically and without exception but not elsewhere. The contrast between attributive and predicative uses of *green* in (22) provides an illustration. The scenario here is that Floyd and Clyde have met on St. Patrick's Day, and that they observe the custom that anyone having failed to wear green in observance of St. Patrick's Day is implicitly inviting an act of minor violence against them.[9] Floyd is sadistic, and joyously observes that Clyde has failed to wear green and has thereby consented to have a minor act of violence performed against him. Clyde

[9] There appears to be some variation among those who have attended American grade schools in the act of minor violence expected, ranging from pinching, the most typical, to punching. This an observation the relevance of which is not linguistic.

objects, however, pointing to the lining on the inside of his jacket, which is green, and uttering (22):

(22) *Clyde (displaying the green lining of his jacket):*
But this jacket is green!

This is a likely defense for Clyde to adopt, and he has said something true. But not so if Clyde had instead uttered (23):

(23) But this is a green jacket!

This is false because it is not sufficient for something to be a *green jacket* that only its lining be green. There is some additional special requirement that is imposed by combining *green* with *jacket* via attributive adjectival modification that is not present when these are combined in other ways.

Another example of this contrast, again involving *green*, might arise upon opening a friend's refrigerator and discovering some particularly moldy bread:

(24) Holy crap—your refrigerator is absolutely revolting! Rotting vegetables! Discolored cheese! Disintegrating fruit!...
a. ...And, ugh, look at this bread! It's green!
b. #...And, ugh, look at this green bread!

The judgment is perhaps a bit less clear-cut here than in the St. Patrick's Day scenario, but things seem to work similarly: bread that has spots of green mold might be said to be *green*, but it cannot truthful be characterized as *green bread*.

The common thread, then, is that the prenominal position introduces an additional, stronger requirement in addition to the lexical semantics of the color adjective, which has to do with the 'way' in which the color adjective is predicated, that is, with how or in what respect the jacket or the bread is green—internally or externally, visibly or not, partly or wholly, etc. It is, of course, well beyond the scope of this discussion to try to isolate this difference, but it might, very loosely, be said to involve what the *principal* color of an object is. Thus green may be the color of the jacket internally or on the inside, but it is not the principal color of the jacket. What counts as the principal color would likely depend on a number of subtle, probably contextual factors and of course also on what the particular object is.[10]

[10] This story is not, of course, sufficient as it stands. One difficulty is that while the jacket in (23) is not a *green jacket*, it is in fact an *internally green jacket*—yet of course 'internally green' cannot be said to be the principal color of the jacket. Pragmatic factors governing the

This, then, could be said to be the special meaning of the position occupied by color adjectives, and expressed as the denotation of a licensing feature [+COLOR]:

(25) $[\![\,[\text{+COLOR}]\,]\!] = \lambda P_{\langle e,t\rangle}\ \lambda A_{\langle e,t\rangle}\ \lambda x_e\,.\,P(x) \wedge A(\text{PRINCIPAL-COLOR}(x))$

The PRINCIPAL-COLOR function maps an individual onto its principal color.[11] Thus [+COLOR] takes the denotation of an NP and that of a color adjective as arguments and yields a property of individuals whose principal color satisfies the color adjective.

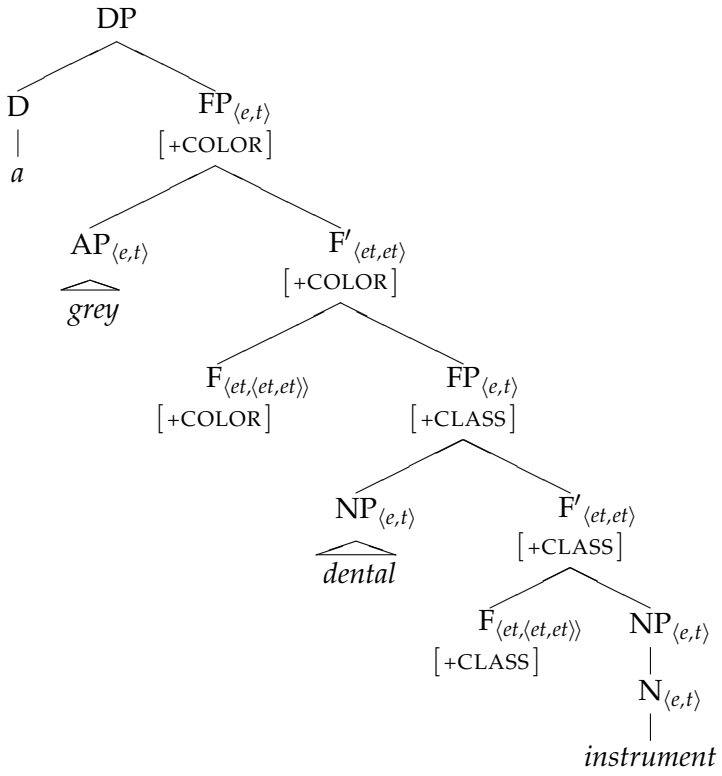
There is, then, some independently observable meaning associated with the position of color adjectives, namely that in (25). But in expressing this meaning, the restriction that only color adjectives can occur as arguments to [+COLOR] was captured as well. The mirroring of color lexical semantics considered above instead falls out as a straightforward selectional restriction of the 'principal color' relation—blue or red or green might be the principal colors of an object, but ugly or dental can never be.

And this, of course, allows the semantics to be distributed across the tree in a way that has the desired result, again with only the stipulation of the relative order of the independently motivated features. So the structure of *grey dental instrument* will be as in (26), and this will be interpreted as in (27):

process by which the color of an object is determined are discussed in Blutner (1998) (and, approached with a somewhat different set of concerns, in the philosophical literature; see Blutner for citations).

[11] Whether this should in fact be a function is not clear to me. Certainly, one might have a *green and black jacket*, and hence perhaps one with two principal colors.

(26)



(27) a. ⟦ *dental* [+CLASS] *instrument* ⟧
= λx . ∃k[dental(k) ∧ instrument(x) ∧ x realizes k]

b. ⟦ *grey* ⟧ = λx . grey(x)

c. ⟦ *grey* [+COLOR] *dental* [+CLASS] *instrument* ⟧
= ⟦ [+COLOR] ⟧(⟦ *dental* [+CLASS] *instrument* ⟧)(⟦ *grey* ⟧)
= λx_e . ∃k[dental(k) ∧ instrument(x) ∧ x realizes k] ∧
grey(PRINCIPAL-COLOR(x))

This approach, then, seems to provide some traction on some difficult problems. But it comes at a price—the phrase structures that were posited here are perhaps more complicated than one might wish, at least in the absence of further evidence of their presence. Still, importantly, it is a price that buys broader empirical coverage in places where it is sorely needed.

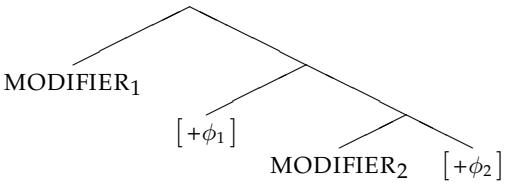
3 The Interpretation of Feature Bundles

3.1 *Why Feature Bundling?*

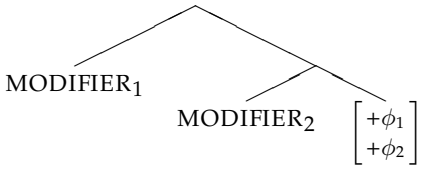
However justified this price might be, it is worth considering a bit further whether the theoretical cost of this sort of approach can be, to stretch the metaphor a bit, bartered down. Might there be a way to execute the same larger idea, and get the same or nearly the same benefits, in a more theoretically conservative way? In this section, I'll develop another way to implement the same larger idea that relies on a theory of feature bundling. The result will be an account that is more conservative phrase structurally—that is, it will involve smaller, less abstract trees with fewer or no phonetically unrealized functional projections.[12]

The core difference in this alternative conception is that the features that serve the mediating role between modifiers and what they modify will not need to be distributed among distinct heads. Indeed, they could in principle all be on the same head. Schematically, the result will be that trees like (28) can instead look like (29):[13]

(28)



(29)



Phrase-structurally, (29) is of course simpler then (28) (if only in the sense of having fewer branches). In that respect, it would be in general be preferable to (28), all else being equal. In particular, this would be the case in the absence of independent syntactic motivation for the intermediate head position $[+\phi_1]$ occupies in (28). The pivot on which this hinges, then, is the 'all else being equal'. To make all else equal, it would be necessary at a minimum to extract from (29) the same advantages that trees like (28)

[12] It should be acknowledged, though, that whether this will actually amount to a lower theoretical cost of course hinges on a number of largely aesthetic judgments, chiefly because the savings may be offset by the costs it imposes in other areas.

[13] My use of ϕ here does not reflect any special connection to ϕ-features—indeed, the features of interest here aren't ϕ-features.

proved to have.

But how? To make progress toward coping with this question, some decision has to be made about how feature bundles like the one in (29) should be interpreted.

Clearly, if the denotations of these features are to be the same as of their unbundled counterparts, they can't simply be interpreted by functional application, for example. That is, given that (28) is interpreted as in (30a), one couldn't for straightforward type-theoretic reasons simply hold the denotations constant and interpret (29) as in (30b):

(30) a. $[\![\,[+\phi_1]\,]\!]([\![\,[+\phi_2]\,]\!]([\![\,\text{MODIFIER}_2\,]\!]))([\![\,\text{MODIFIER}_1\,]\!])$
b. $[\![\,[+\phi_1]\,]\!]([\![\,[+\phi_2]\,]\!])([\![\,\text{MODIFIER}_2\,]\!])([\![\,\text{MODIFIER}_1\,]\!])$

This could, of course, be taken as an indication that the denotations *shouldn't* be held constant—perhaps the $[+\phi_1]$ that occurs in (28) and (30a) can't be the same $[+\phi_1]$ that occurs in (29) and (30b). But merely adjusting the types in this way, and consequently distinguishing bundled and unbundled instances of what otherwise would seem to be the same feature, has some highly undesirable consequences. If we would like $[+\phi_1]$ to occur in a single language in both bundled and unbundled forms, there would have to be two distinct interpretations for this single feature, a kind of featural lexical ambiguity that would have to be propagated throughout the lexicon for every such feature. If we would like $[+\phi_1]$ to occur unbundled in some languages and bundled in others, this would require this sort of type-theoretic distinction across lexicons. Yet it seems likely that the meaning of functional (as opposed to lexical) linguistic material is subject to severe cross-linguistic constraints, particularly type-theoretically. Famously, for example, determiners seem to be conservative across languages, and generalized quantifier theory has at its heart the idea that determiners as a class denote functions that yield generalized quantifiers; Matthewson (1996, and elsewhere) suggests that cross-linguistic semantic variation is highly constricted in at least this way; and aspectual morphemes may consistently relate properties of events and properties of intervals across languages (Klein 1994, Kratzer 1998).

This difficulty cannot simply be taken as evidence against feature bundling. In one form or another, under one name or another, it's a pervasive notion in the grammar. Indeed, if one were to hew strictly to the notion that distinct syntactic features always occupy distinct nodes, there would be no real distinction between features and null morphemes more

generally.[14] In some sense, the whole point of features is that they can be bundled—that is, they exist to provide a way of talking about a proper subset of the properties of a lexical item without structurally decomposing it.

The real difficulty confronted here, then, is with functional application itself. It just doesn't seem to be the right operation for interpreting the elements of a feature bundle. Certainly, however fundamental an operation functional application is, it isn't grammatically holy, and alternatives should be considered. If the denotations of features are to stay the same in bundled and unbundled forms, what appears to be necessary instead is (something like) function composition. In its general form, this is not a new idea. That function composition play a role in the grammar is a fundamental assumption of Variable Free Semantics (Jacobson 1999 and elsewhere), and von Fintel (1995) suggests that is an engine of semantic historical change as well. And taking this kind of approach specifically below the word level (i.e., below X^0) has antecedents including Di Sciullo and Williams (1987) and Kratzer (2000). In light of this, and particularly in light of this independent evidence for its necessity below X^0 as a kind of morphological rule, it seems natural to take this strategy toward the interpretation of features (which are, after all, sub-lexical entities). To execute this, a distinct semantic rule will be necessary, but of course one would be necessary independently (irrespective of mode of composition) to encode in the grammar how feature bundles are interpreted, if only because they don't meet the structural description of a functional application rule (at least as it is formulated in e.g. Heim and Kratzer 1997).

3.2 *A Brief Interlude: Function Composition*

Before proceeding further, it may be useful to briefly illustrate function composition itself. (If it is not useful, one can safely proceed to section 3.3.) Informally, function composition involves applying one function to the result of another. It is the operation represented by $\circ$ in (31):

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[14] An alternative not so easily set aside is to suppose that distinct features always occupy distinct nodes *at LF*—indeed, this seems plausible in a number of respects, and would avoid, via syntactic means, many of the difficulties encountered here (cf. the 'feature scattering' of Giorgi and Pianesi 1997 and the treatment of number features in this spirit of Kratzer 2002). This would, of course, require a dramatic accordion-like unpacking of trees at LF into structures far larger than they would otherwise be, which might provoke exactly the same aesthetic objections bundling of features may be able to address. More generally, this approach in any form would wind up resembling quite closely the first, bundle-free implementation considered in previous sections, and so in this respect it's is the less interesting course to take in the context of the current discussion.

(31) $A \circ B = \lambda c\,.\,A(B(c))$

So, to take an unrelated linguistic example, one could in principle function-compose the denotations of *help* and *build* in (32):[15]

(32) Clyde will help build our mechanical ferret.

That is, instead of first interpreting *build our mechanical ferret*, as one normally would, function composition would make it possible to interpret *help build* first while maintaining exactly the same denotations for all the terminal nodes in the sentence. The complex denotation of *help build* could than be applied to the denotation of *our mechanical ferret*, effectively 'postponing' interpretation of this argument. The order in which things are interpreted, then, would reflect a constituent structure like (33b) rather than (33a):

(33) a. Clyde will help [build our mechanical ferret].
b. Clyde will [help build] our mechanical ferret.

Assuming the denotations in (34), the result of function-composing *help* and *build* would be (35):

(34) a. $[\![\,\textit{help}\,]\!] = \lambda P_{\langle s,t\rangle}\ \lambda e\,.\,\exists e'[P(e') \wedge \text{help-to-happen}(e')(e)]$
b. $[\![\,\textit{build}\,]\!] = \lambda x\ \lambda e'\,.\,\text{build}(x)(e')$
c. $[\![\,\textit{help}\,]\!] \circ [\![\,\textit{build}\,]\!]$
$= \lambda x\,.\,[\![\,\textit{help}\,]\!]([\![\,\textit{build}\,]\!](x))$
$= \lambda x\ \lambda e\,.\,\exists e'[\text{build}(x)(e') \wedge \text{help-to-happen}(e')(e)]$

The result can be applied to *our mechanical ferret*:

(35) $[\![\,\textit{help build}\,]\!]$(our-mechanical-ferret)
$= \lambda e\,.\,\exists e'[\text{build}(\text{our-mechanical-ferret})(e') \wedge$
$\text{help-to-happen}(e')(e)]$

This yields exactly the same denotation for *help build our mechanical ferret* as the normal procedure would have:

[15] For the sake of the example, I will simply skip over the interpretation of all sorts of functional structure that may be present in the extended projection of *build*. More generally, none of this is intended as an analysis of this construction, or to suggest that there is any particular merit of using function composition in interpreting it. This is all only to illustrate function composition in a way that bears some resemblance to what will be proposed below.

(36) ⟦ *help build our mechanical ferret* ⟧
= ⟦ *help* ⟧(⟦ *build* ⟧(⟦ *our mechanical ferret* ⟧))
= λe . $\exists$e′[build(our-mechanical-ferret)(e′) $\wedge$
help-to-happen(e′)(e)]

The effect of function composition, then, is to 'postpone' the interpretation of an argument.

3.3 *The Feature Rule*

There is, however, a slight complication that should be overcome before we can make use of this—function composition has the effect of 'postponing' the interpretation of exactly one argument. But, in light of other assumptions about how arguments are introduced, this will not be enough. Sometimes, multiple arguments will have to be postponed in this sense. If a feature and a transitive verb are interpreted by function composition, for example, exactly one argument would be postponed, namely, the object; but if that same feature and a *di*transitive verb were to be interpreted this way, it would be necessary to postpone *two* arguments, namely, both objects of the ditransitive verb. So things have to be a little more flexible.

One way to achieve this is to borrow the 'Geach rule' from Variable Free Semantics and categorial grammar, though in a much more limited way. This rule is, in Jacobson (2000)'s words, 'just a unary (Curry'd) version of function composition', and is expressed as the function g (the formulation here is Jacobson's):

(37) g(α) = λV λC . α(V(C))
for V of type $\langle c,a \rangle$ and C of type c

Applying g to A and then applying the result to B yields the same result as having function composed A and B in the more ordinary way:

(38) g(A)(B) = [λC . A(B(C))] = A $\circ$ B

This can provide a means of extending or generalizing function composition in a way that will provide the necessary flexibility. Applying g once has the effect of 'skipping over' one argument; applying it more than once, though, makes it possible to 'skip over' more than one argument. So in (39), one individual argument of B is skipped over; in (40), two individual arguments are:

(39) A is of type $\langle et,et\rangle$ and B is of type $\langle e,et\rangle$
a. g(A) = λP λx . A(P(x))
b. g(A)(B) = λx . A(B(x))

(40) A is of type $\langle et,et\rangle$ and B is of type $\langle e,\langle e,et\rangle\rangle$
a. g(A) = λP λx . A(P(x))
b. g(g(A)) = g(λP λx . A(P(x)))
= λQ λy . [λP λx . A(P(x))](Q(y))
= λQ λy λx . A(Q(y)(x))
c. g(g(A))(B) = λy λx . A(B(y)(x))

This effect is exactly what's needed here. But this particular way of thinking about it, in which g is a kind of type-shift that can be applied repeatedly, gives it the flavor of a grammatical operation of some sort, and particularly when interpreting the object language directly, one that might be expressed in the syntax and perhaps even in some language with overt morphology. This might, of course, be precisely the case, but in the current context it is for this reason at least expositorily awkward. To express the same idea of a more flexible kind of function composition via repeated geaching, the operation $\circ\circ$ in (41) will be used as a kind of shorthand to represent this more promiscuous cousin of function composition:

(41) A $\circ\circ$ B = g^n(A)(B)
where g^n is n instances of applying g and n is the smallest integer $\geq$0 such that B is in the domain of g^n(A)

So $\circ\circ$ is unlike function composition in that it skips over as many arguments as it needs to. Intuitively, the effect is to peel off as many lambdas from B as necessary to have something of which A can be predicated, then prefix these lambdas to the result.

With this in place, feature bundles can now be interpreted by combining the denotations of the features with the $\circ\circ$ operation. More precisely, the rule for interpreting feature bundles will be as in (42):[16]

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[16] It might be possible to simplify this rule. Because $\circ\circ$ is associative, it would be sufficient to assume that any immediately adjacent features in a feature structure can be interpreted via the $\circ\circ$ operation. Thus the rule might be something like:

(i) FEATURE RULE (ALTERNATIVE FORMULATION)
If $[\,\phi_1\,]$ and $[\,\phi_2\,]$ are features or collections of adjacent features,
$[\![\, \left[\begin{smallmatrix}\phi_1\\ \phi_2\end{smallmatrix}\right] \,]\!] = [\![\,[\,\phi_1\,]\,]\!] \circ\circ [\![\,[\,\phi_2\,]\,]\!]$

An independent rule would be necessary to combine the features' denotation with that of the head that bears them:

(42) FEATURE RULE
If α is a terminal node bearing the features $[\phi_1]$ through $[\phi_n]$,

$$\left[\!\!\left[\begin{array}{c} \alpha \\ \left[\begin{array}{c} \phi_1 \\ \vdots \\ \phi n \end{array} \right] \end{array} \right]\!\!\right] = [\![[\phi_1]]\!] \circ\!\circ \cdots \circ\!\circ [\![[\phi n]]\!] \circ\!\circ [\![\alpha]\!]$$

This, then, requires the denotations of features to be combined with each other by the $\circ\!\circ$ operation starting at the top of the feature bundle and working toward the bottom, then combining the result by $\circ\!\circ$ with the denotation of the node bearing the feature bundle. This loosening up of the interpretive procedure is implemented very narrowly here, targeting only feature structures.[17] Above the word level, no new principles of interpretation will be available that weren't available before.

A crucial but unusual assumption underlying (42) is that the relative order of features in a feature structure is significant. This warrants some elaboration, and I will return to this in 3.4 after a brief illustration of how this machinery works.

The principal appeal of this implementation is that it can achieve exactly the same interpretation as the implementation without feature bundling, but with more minimal trees. Considering again one of the examples that led to the bundle-free approach, repeated in (43), a simpler syntactic structure can now be assigned:

(43) a steel dental instrument

For example, we could now place the [+CLASS] feature that introduces

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(ii) FEATURE RULE (ALTERNATIVE FORMULATION): PART II
If α is a terminal node bearing the feature structure ϕ,

$$\left[\!\!\left[\begin{array}{c} \alpha \\ [\phi] \end{array} \right]\!\!\right] = [\![[\phi]]\!] \circ\!\circ [\![\alpha]\!]$$

I don't follow this course mostly because its a bit more conceptually slippery, and because the simplification in (i) comes at the price of having to state (ii) separately.

[17] Indeed, this formulation is probably *too* restrictive. It may be useful to assume that something like this is available below X^0 more generally, as a specifically morphosemantic means of assembling meanings. A bit of relatively direct independent motivation for this comes from the suggestion of von Fintel (1995) that diachronically, the meaning of *many* developed by function-composing the meaning of a pre-existing adjective *many* and a null determiner. If, as he proposes, this is a regular avenue of historical change, it would be somewhat odd in that it would be possible only when one of the morphemes it targets has precisely one argument to 'skip over', which doesn't seem to be a grammatically relevant property. But supposing that the relevant operation is $\circ\!\circ$ instead would eliminate this restriction.

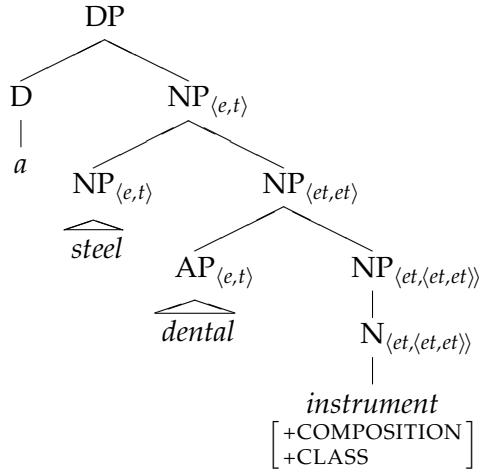
the adjective directly on the noun rather than according it an independent phrase-structural location.[18] No further syntactic projections will be required (to achieve the ends sought here). As far as the semantics is concerned, the position the modifier occupies need only be at the right hierarchical level.

This can be achieved by adjunction—the course I'll adopt here—or alternatively, by supposing the modifier occupies a specifier position as before. The major disadvantage of this is that an independent explanation is required for why the modifier seems to necessarily occupy a left branch, and not merely a particular hierarchical position. Here one could appeal to e.g. the Linear Correspondence Axiom (Kayne 1994), or something like the linearization principles Ernst (2002) proposes for adverbs. Of course, this would not be a disadvantage if it were desirable to suppose that certain modifiers introduced this way occupy left branches, and certain others don't—if distinct principles govern linearization, linear position could vary among these modifiers independent of hierarchical position. Whether this would in fact be desirable is, I think, not an easily resolved empirical question, though certainly one that merits continued inquiry. On the other hand, the advantage of taking the specifier approach is that it ensures entirely on its own that the modifier will occupy a left branch. But in order to provide the modifier with a specifier position to occupy, it would be necessary to assume multiple specifiers.[19] Pursuing the adjunction analysis here, then, (43) can be assigned the structure in (44):

[18] In this sense, the Feature Rule in (42) actually introduces analytical possibilities not only by permitting feature bundles to be interpreted, but also by permitting features borne by semantically interpreted heads to be interpreted, too.

[19] Of course, the modifier could also be placed in the specifier of a distinct functional projection—but this would eliminate the phrase-structural simplicity that is an important advantage of the feature-bundling advocated here.

(44)



The crucial step in interpreting this structure is in (45). The Feature Rule combines the denotation of *instrument* in (45a) and the denotation of the features it bears in (45b) and (45c)—importantly, both precisely the same denotations assumed earlier—to yield (45d):

(45) a. $[\![\textit{instrument}]\!] = \lambda x \,.\, \text{instrument}(x)$

b. $[\![[\,\text{+COMPOSITION}\,]]\!] = \lambda P_{\langle e,t\rangle}\ \lambda C_{\langle e,t\rangle}\ \lambda x_e \,.\, P(x) \wedge \exists y[C(y) \wedge x \text{ is composed of } y]$

c. $[\![[\,\text{+CLASS}\,]]\!] = \lambda P_{\langle e,t\rangle}\ \lambda A_{\langle e,t\rangle}\ \lambda x_e \,.\, \exists k_e[A(k) \wedge P(x) \wedge x \text{ realizes } k]$

d. $\left[\!\!\left[\begin{array}{c} \textit{instrument} \\ \left[\begin{array}{l}\text{+COMPOSITION}\\ \text{+CLASS}\end{array}\right] \end{array} \right]\!\!\right]$

$= [\![[\,\text{+COMPOSITION}\,]]\!] \circ\circ [\![[\,\text{+CLASS}\,]]\!] \circ\circ [\![\textit{instrument}]\!]$

$= [\![[\,\text{+COMPOSITION}\,]]\!] \circ\circ [\lambda A_{\langle e,t\rangle}\ \lambda x_e \,.\, \exists k_e[A(k) \wedge \text{instrument}(x) \wedge x \text{ realizes } k]]$

$= \lambda A_{\langle e,t\rangle} \,.\, [\![[\,\text{+COMPOSITION}\,]]\!](\lambda x_e \,.\, \exists k_e[A(k) \wedge \text{instrument}(x) \wedge x \text{ realizes } k])$

$= \lambda A_{\langle e,t\rangle}\ \lambda C_{\langle e,t\rangle}\ \lambda x_e \,.\, \exists k_e[A(k) \wedge \text{instrument}(x) \wedge x \text{ realizes } k] \wedge \exists y[A(y) \wedge x \text{ is composed of } y]$

So $\left[\!\!\left[\begin{array}{c} \textit{instrument} \\ \left[\begin{array}{l}\text{+COMPOSITION}\\ \text{+CLASS}\end{array}\right] \end{array} \right]\!\!\right]$ is a kind of 'augmented' (in the sense of McConnell-Ginet 1982) form of *instrument*, one that has had additional arguments introduced just as a verb might be said to acquire additional arguments in causatives. Simple *instrument*, which has a straightforward common noun denotation, and the features it bears, each of which is a function that applies to NP denotations, are combined by the Feature Rule so

that $\begin{bmatrix} \textit{instrument} \\ \text{+COMPOSITION} \\ \text{+CLASS} \end{bmatrix}$ will have a denotation that takes as its arguments first a classificatory adjective denotation—here, *dental*—then a composition-noun denotation—here, $[\![\, \textit{steel} \,]\!]$—and yields an NP denotation. From this point, things proceed by functional application in the familiar way. Again assuming exactly the same denotations for everything as before, the DP is interpreted as in (46):

(46) a. $[\![\, \textit{dental} \,]\!] = \lambda k_e \,.\, \text{dental}(k)$

b. $[\![\, \textit{steel} \,]\!] = \lambda y \,.\, \text{steel}(y)$

c. $\left[\!\!\left[\textit{steel dental} \begin{bmatrix} \textit{instrument} \\ \text{+COMPOSITION} \\ \text{+CLASS} \end{bmatrix} \right]\!\!\right]$

$= \left[\!\!\left[\begin{bmatrix} \textit{instrument} \\ \text{+COMPOSITION} \\ \text{+CLASS} \end{bmatrix} \right]\!\!\right] ([\![\, \textit{dental} \,]\!])([\![\, \textit{steel} \,]\!])$

$= \lambda x_e \,.\, \exists k_e[\text{dental}(k) \wedge \text{instrument}(x) \wedge x \text{ realizes } k] \wedge$
$\exists y[\text{steel}(y) \wedge x \text{ is composed of } y]$

An important feature of this system is that it establishes precisely the same semantic bond as the original implementation between a modifier and the feature that introduces it—as before, the modifier is an argument of the feature. Thus for precisely the same reasons as before, there is no need for a syntactic mechanism (feature checking, say, as in Cinque 1999) to do this work.

And as before, the hierarchical order in which modifiers occur will mirror the order in which the features occur. Because of the way the Feature Rule and the $\circ\circ$ operation are defined, a modifier introduced by a feature higher in the feature structure will occur higher than one introduced by a feature lower in the feature structure, as this example illustrates. Crucially, the modifier corresponding to the higher feature is introduced first (the $\lambda A_{\langle e,t \rangle}$ above, which came from $[\,\text{+CLASS}\,]$ and will be saturated by the classificatory adjective) and the modifier corresponding to the lower feature is introduced later (the $\lambda C_{\langle e,t \rangle}$ above, which came from $[\,\text{+COMPOSITION}\,]$ and will be saturated by the composition noun.

The denotation in (46) is precisely the same denotation as arrived at in the original, bundle-free account. Thus the largely the same mediated approach to the interpretation of these modifiers—and the fundamentally the same understanding of the link between modifier position and interpretation—is achieved here without requiring specialized projections.

3.4 *Bundled Feature Order*

Just as in any theory that relies on functional projections, things hinge to a large extent on the order in which these features occur. On the account initially proposed, their ordering could follow from the same principles—or stipulations—as the ordering of functional heads, and nothing special needed to be said. Here, though, what is relevant, in light of the way the Feature Rule is constructed, is the order of these features in a feature structure. This is a distinct notion. Yet, fundamentally, the order of features here is intended to express part of the same thing—it's simply a way of talking about the order in which they are interpreted. The only substantive difference is the shape of the trees. So it would be desirable not only for the order of features in a feature structure to mirror the order of features when distributed across different nodes, but also for this ordering to be derived the same way.

To the extent that the order of functional heads can be explained semantically—say, by facts about semantic selection broadly construed—nothing further would need to be said here with respect to the order of features in a feature structure, since their semantic relations are defined by the Feature Rule.

But a theory of functional head order that doesn't rest wholly on semantic explanation would not carry over so straightforwardly. Because such a theory is very likely to be built on some notion of c-command, though, we can remedy this by elaborating the definition of c-command so that some features can c-command others they are bundled with. More precisely, the precedence relation associated with a feature structure—graphically, the top-to-bottom order to which the Feature Rule appeals—can be understood to be itself a kind of c-command. The definition of c-command, then, could be extended (disjunctively, which isn't ideal) to include something like (47):

(47) If a feature $[\phi_1]$ precedes (graphically, is above) a feature $[\phi_2]$ in a feature structure, $[\phi_1]$ c-commands $[\phi_2]$

This adapts the likely foundation of any syntactic theory of functional head order to feature structures, and so should make it carry over directly. If, for example, such a theory that takes the form of a simple universal list of stipulations about possible c-command relations—say, that α must c-command β, and that β must c-command γ—these stipulations would ensure that if α and β are features, they can only be bundled in such a way that α is above β.

There is a different and more radical way of looking at this issue, though. It seems to be a fact about modification—and one that doesn't seem to be avoidable—that the syntactic category of an expression, and thus also the syntactic category of its head, at least partly determines what modifiers it may have. Thus it is the fact that *instrument* is a noun that permits it to have as modifiers, among many other things, classificatory adjectives and composition attributives and color adjectives. Put in terms of features, it is because *instrument* bears an [N] feature that it can bear the features [+CLASSIFICATORY] and [+COMPOSITION] and [+COLOR]. It might be desirable for this to follow from something. A particularly bold analytical move one might make here is to actually understand the [N] feature as a kind of abbreviation for features like [±CLASSIFICATORY] and [±COMPOSITION] and [±COLOR]—that is, for the features (at least the modifier-licensing features of interest here, but perhaps others as well) that collectively reflect the syntactic properties of a noun:[20]

(48) [N] abbreviates $\begin{bmatrix} \vdots \\ \pm\text{CLASSIFICATORY} \\ \pm\text{COMPOSITION} \\ \pm\text{COLOR} \\ \vdots \end{bmatrix}$

And of course, other categories, including both lexical categories like V and functional ones like T and Deg, might be understood in a corresponding way, as abbreviations for the modifiers they accept. This is, in a sense, a very direct way of encoding into the grammar the idea that syntactic categories should be defined by the syntactic environments in which they occur. As bold a move as this seems, it is not clear that it amounts to a rejection of any profound assumptions. The tradition of decomposing lexical categories into more basic features (e.g., understanding the category P to abbreviate $\begin{bmatrix} -\text{N} \\ -\text{V} \end{bmatrix}$) has a long history in generative grammar, and this is certainly entirely consistent with that. Beyond that, as Baker (2003) notes, this has for the most part not been taken much further.[21]

This has an unexpected advantage that suggests there might be something right about it. One of the more important open questions

[20] The features are represented with ±values here to reflect that even when negatively valued, they are in some sense present, if only because a noun might have been lexically inserted with a positive value for that feature instead.

[21] Though of course, Baker proceeds to do so, and arrives at a theory that *is* significantly different from the approach that (48) suggests.

currently in research into the syntax-semantics interface is to what extent the notion of syntactic notion of interpretability, which of course plays a central and in many ways driving role in contemporary syntax, can be identified with the semantic notion of interpretability. It would of course be a very interesting and highly desirable discovery for these to turn out to be the same. One roadblock in the program of identifying them, though, is that it often seems to be necessary for the syntax to refer to lexical categories as interpretable features—yet it is not obvious what meaning is contributed by simply being a noun, for example, apart from the meaning of individual nouns. The view (48) reflects, though, suggests an answer. Each of the features in (48) has, when positively valued, an interpretation (and when negatively valued, can be assumed to denote the identity function). It would follow then, that the D feature—that is, the collection of features that are characteristic of a determiner—would be interpretable in the semantic sense on a determiner and not on a tense morpheme. This, of course, is the basis of the explanation of the EPP in English in which a subject position must be filled to check an uninterpretable D feature on T. It is normally necessary to stipulate that the D feature is uninterpretable on T; here, it would follow independently from the semantic types of the denotations of the features that the D feature abbreviates.

So at this point two largely distinct implementations of the larger analytical idea have been suggested. Each has its advantages, and of course it's ultimately an empirical question which is preferable. Importantly, though, the second implementation is in some respects just a more flexible version of the first, and it can comfortably be 'mixed' with it. It may be the case—and indeed, seems likely—that languages might vary in how they group such modifier-licensing features. Some languages may group together in a single node features other languages distribute among several, for example. The important thing is that on the second implementation, this is possible, but nothing that was possible on the first is ruled out. I regard this as an advantage, providing analytical flexibility that is probably necessary. Of course, one could reasonably regard it instead as an empirically undermotivated weakening of the more restrictive first implementation, justified as it is mostly by the desire to prune trees. Either way, it does demonstrate that a phrase structurally complex analysis of an empirical phenomenon can, on these assumptions about feature bundle interpretation, be translated into a phrase structurally simpler counterpart without while maintaining the semantics of all the linguistic expressions involved.

4 The Bigger Picture

This paper has focused on one relatively narrow set of empirical puzzles, but the larger proposal about the interpretation of feature bundles has considerably broader applicability. Most straightforwardly and perhaps most obviously, it can extend in a way that's fairly analogous to other issues surrounding modifier order. But it can in fact be applied in many of the same places one might posit functional projections, capturing the roughly the same idea in a more structurally economical way. One such place might be the relationship between the T and Asp heads. Kratzer (1998) proposes an understanding of the interpretation of tense and aspect morphemes along the lines of (49):[22]

(49) $[\![[_{Asp} [\text{PERFECT}]]]\!] = \lambda P_{\langle e,t\rangle} \, \lambda t_i \, . \, \exists e[P(e) \wedge \tau(e) < t]$

(50) $[\![[_{T} [\text{PAST}]]]\!] = \lambda P_{\langle i,t\rangle} \, . \, \exists t[P(t) \wedge t < t_0]$

Here, aspect provides the relation between the event time and the reference/topic time (building on informal proposals of Klein 1994) and tense provides the relation between reference/topic time and utterance time. In most cases, considerable evidence can be adduced for keeping T and Asp structurally distinct. But it seems reasonable to suppose that some language might seem to fail to draw a clear distinction between the two—that is, to glob T and Asp together lexically in a single feature bundle. On the assumptions advocated here, this would give rise to a perfectly well-defined interpretation for the feature bundle, in (51):

(51) $[\![[_{T} [\text{PAST}]]]\!] \circ\circ [\![[_{Asp} [\text{PERFECT}]]]\!]$
$= \lambda P_{\langle e,t\rangle} \, . \, [\![[_{T} [\text{PAST}]]]\!]([\![[_{Asp} [\text{PERFECT}]]]\!](P))$
$= \lambda P_{\langle e,t\rangle} \, . \, [\![[_{T} [\text{PAST}]]]\!](\lambda t_i \, . \, \exists e[P(e) \wedge \tau(e) < t])$
$= \lambda P_{\langle e,t\rangle} \, . \, \exists t[\exists e[P(e) \wedge \tau(e) < t] \wedge t < t_0]$

Thus this tense-aspect conglomeration is interpreted as expressing the information provided by both tense and aspect—that is, it expresses both the relation between event time and reference/topic time, and the relation between reference/topic time and utterance time. Moreover, it will map a VP denotation directly onto a TP denotation, 'skipping over' the intermediate level that would otherwise be present at which the verbal projection would denote a property of intervals.

[22] Intervals here are of type i and are represented with the variable t, and t_0 is the utterance time.

One might imagine similar applications in the nominal domain, with respect to bundling of determiner and noun features, or perhaps more likely, determiner and number features, say. So one could certainly reject the analysis of the facts about English prenominal modification offered here without rejecting this larger view of how feature bundles are interpreted.

The rule that drives these interpretations was called the 'Feature Rule' here, but there is something that seems a bit inadequate about that. It seems that what one might really want to say instead is simply that function composition (or more precisely the Geach-y close relative $\circ\circ$ used here) is available quite generally as the primary and perhaps only mode of semantic composition below the word level—that is, below X^0—and that the interpretation of feature bundles is really only a special case of that. It certainly isn't necessary that things should have been this way, but it's quite natural—the distinction between features that are spelled out overtly in the morphology and ones that aren't isn't, after all, so great from the point of view of the semantics.

To summarize, then, the proposal here is to interpret feature bundles by (a relative of) function composition, proceeding in the way made explicit in a specialized rule of semantic composition, dubbed here simply the Feature Rule. On this basis an account was proposed of a number of recalcitrant and to my knowledge unaccounted-for facts about English prenominal modification. Because of the additional syntactic flexibility this the Feature Rule makes possible, this account could be implemented without positing any functional projections for which there doesn't seem to be any obvious independent motivation. Importantly, though, because of the way the Feature Rule is structured, it allows features to have precisely the same denotations whether bundled or not, whether in a distinct functional head or not. Thus no analytical avenues have been cut off—under these assumptions features could be distributed among distinct heads where there is motivation for additional structure. What results is a kind of accordion-like structure for features, in which they can fold out across many nodes or contract into fewer or even one, all while maintaining the same semantic relationship to each other.

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