How nominal compounds are modified by two adjectives[1]

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Basing itself on a corpus of one thousand complex NPs, this study investigates the relationships that two attributive adjectives contract with the constituents of nominal compounds of varying size in English (e.g. *new basic safety standards*). Essentially, there are four logically possible relationships: (i) both adjectives modify the nominal head, (ii) both adjectives modify the nominal modifier, (iii) the first adjective modifies the head and the second adjective the modifier and (iv) the first adjective modifies the modifier and the second adjective the head (crossed modification). While options (i) and (iii) are strongly represented in the data, crossed modification is not at all present. Across all compound sizes, at least three factors shape the empirical patterns: a functional factor whereby major heads are more easily singled out than minor heads, which in turn are more available than modifiers; a structural factor whereby more deeply embedded constituents are less available than more independent constituents; and a proximity effect which encourages the modification of the first noun by the second adjective. There may be an additional saturation effect which discourages the modification of one noun by two adjectives. On the face of it, the non-occurrence of crossed modification may be connected to the well-known ban on crossing association lines. However, despite its descriptive adequacy, this principle is unconvincing. Instead, a functional explanation is proposed which centres on the possibility of working out modification relationships. Initial steps are taken towards developing a model of when (and why) the no-crossing constraint is inviolable, violable or non-existent.

Keywords: syntactic modification, morphological modification, compounding, no-crossing constraint, formalism vs. functionalism

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1. Introduction

One of the fundamental issues in syntax is whether a given element can, or cannot, modify another element within a larger structure. Wells's (1947) classic example in (1) nicely illustrates the possibilities of, and restrictions on, adjective modification in English (for other examples, see Woisetschlaeger 1983: 146, Borer 1988: 48 and Siemund 1998: 282).

(1) The old men and women weren't sent to the battlefield.

Whereas *old* can modify *men* alone as well as the conjoined nominal, it cannot modify *women* alone. This asymmetry is predicted by the proximity principle (e.g. Givón 1991), which describes the effect of linear distance on syntactic relations: the closer the noun is to the adjective, the higher the likelihood of the former being modified by the latter.

Complex units exist not only at the syntactic level (e.g. the conjoined nominal in (1)) but also at the morphological level. Therefore, when extending the problem of adjectival modification to compounding, the question arises how compounds can be modified by adjectives. It is useful to distinguish among three types of modification. To begin with, consider (2).

(2) a. a large sweet shop
b. a large hardware shop

Theoretically speaking, the adjective *large* could modify the modifier of a compound (*sweet* in (2a)), its head (*shop*) or the entire compound (*sweet shop*). Clearly, modifier modification is a highly remote possibility in (2). It makes much more sense to associate the adjective with the head of the compound, such that, largely speaking, the adjective denotes the size of stores. However, a closer look reveals that *large* does not uniformly describe the size of shops. In other words, despite the identity of the adjective, the images evoked in (2a) and (2b) differ: a large hardware shop tends to be comparatively larger than a large sweet shop, probably because garden and household tools are of a larger average size than sweets. Thus, both *hardware/sweet* and *shop* go into the interpretation of *large*, and the adjective may therefore be assumed to modify the entire compound (called hierarchical modification by Sproat & Shih 1991). However, there is a clear asymmetry between the two constituents of the compound. The adjective is much more strongly oriented towards the second than the first noun. Even though it modifies the whole compound, it may be argued to single

out the head noun to a far greater extent than the modifier. The reading "a large shop" approaches the intended meaning much better than "a large sweet", which is certainly off the mark.

The second type of modification is illustrated in (3).

(3) a. divisional command post
b. nuclear fuel cycle

The basic characteristic of (3) is that the adjective modifies the compound as an indivisible unit. It cannot modify the constituents individually. In (3a), for example, *divisional command* makes as little sense as *divisional post*. Thus, the asymmetry between head and modifier observed in (2) is lacking in (3), and justifies keeping the modification patterns in (2) and (3) distinct.

It is well known that the constituents of compounds may come from different word classes (e.g. Selkirk 1982). Adjectives may reach into nominal compounds and thereby create substructures with nominal constituents. This freedom gives rise to the third modification type, as exemplified in (4).

(4) a. used car dealer
b. Cold War years

In contradistinction to (2), the adjectives in (4) modify the adjacent noun rather than the entire compound, whereby these adjective–noun units function as the modifier of the overall structure. Cases such as (4) show that adjectives may link up with individual constituents in compounds. Hence, adjectives have the option of modifying a single noun or a combination of nouns as well as the modifier or the head of the compound or the entire compound.[2]

As has been repeatedly observed, nominal compounding is recursive in English (e.g. Mukai 2008). Adjectives may accordingly form part of larger compounds. The four possibilities of modification offered by four-noun compounds are exemplified below. The brackets indicate the scope of the adjective.

(5) [private client] fund management business
(6) [big brand name] computer makers

[2] Henceforth, we will make use of a shorthand description by referring to the modification of the maximal projection of a nominal constituent simply as the modification of an individual constituent of a compound.

(7) [European Exchange Rate Mechanism] system
(8) [diminishing reactor safety research budgets]

As can be seen, the scope of the adjective gets progressively wider from (5) to (8). In (5), *private* links up with *client* in much the same way as the adjectives link up with their adjacent nouns in (4). The other three examples illustrate the modification of progressively larger compounds within compounds. The adjective modifies the two-part compound *brand name* in (6), the three-part compound *Exchange Rate Mechanism* in (7) and the four-part compound *reactor safety research budgets* in (8).

There is a major difference between examples (5)–(7) on the one hand and (8) on the other. Whereas the adjective is integrated into the compound in (5)–(7), it is external to it in (8). Example (8) is a typical case of syntactic modification, with the adjective modifying the head or the entire compound; the other cases illustrate compound-internal modification, with the adjective ignoring the head of the compound. This contrast reflects Liberman & Sproat's (1992) distinction between syntactic and morphological modification. The former involves the modification of lexical units (such as words) while the latter describes the modification of morphological units (such as compound constituents).[3]

In a recent study, Berg (2011) conducted a quantitative analysis of the modification patterns in single (attributive) adjective + (nominal) compound structures (e.g. *fixed exchange rate system*). He found that no maximal projection of a constituent of a compound was immune to adjectival modification, irrespective of the size of the compound and the position and function (i.e. head or modifier status) of the nominal constituent within the compound. Influencing the modification patterns were a functional and a structural factor: the status of head or modifier and depth of embedding. In particular, heads of compounds were found to be modified significantly more often than modifiers; moreover, resistance to adjectival modification increased with increasing depth of embedding. A third factor, viz. linear proximity, played a more limited role. The functional factor

[3] This analysis is apparently at odds with Huddleston & Pullum's (2002) claim that morphological modification is not possible in compounds. In their view, cases like (4), for example, are not compounds. They argue that allowing morphological modification inside compounds would blur the distinction between syntax and morphology. In the light of the data discussed in Lieber (1992) as well as in the theoretical discussion (Section 4) of the present article, this is a desirable rather than an undesirable conclusion.

was observed to be more robust than the structural one. The strength of these factors was largely independent of compound size.

Given that it is a truism that nouns, whether simple or morphologically complex, can be modified by more than one adjective, it would seem only natural to extend the above-mentioned study to investigate the modification patterns of two adjective + nominal compound sequences. This project would be of limited interest if both adjectives invariably modified the same constituent of a given compound. If, however, the two adjectives could single out different constituents, a variety of modification types would arise. Our immediate aim is therefore to examine whether different adjectives may modify different constituents and to uncover possible constraints on the modification patterns. A comparison will be carried out between the single-adjective and the two-adjective + multi-noun combinations with a view to ascertaining whether the two structures are subject to the same principles. In an attempt to make sense of the empirical patterns, both formal and functional approaches will be considered. The ultimate theoretical objective is to outline an account of adjectival modification which explains the occurrence or non-occurrence of the various modification patterns.

2. Method

The empirical issue of this article was addressed using a corpus-linguistic approach, with the 100m-word British National Corpus (BNC) providing the basis for the ensuing investigation. The BNC's size allows one to extract a sufficiently large number of relevant items for statistical treatment. The upper length at which compounds occur with some frequency is four constituents. It was decided therefore to focus on two-, three- and four-noun compounds. The BNC search term for two-noun compounds was "&aj?&aj?&NN?&NN?". Longer compounds require one (or more) additional "&NN?" specification(s) at the end of the search string. All three- and four-noun compounds that occurred in the BNC (and were preceded by two adjectives) were included in the analysis. As the number of doubly modified two-noun compounds ran in the thousands, a sample was constructed which was designed to be of a size similar to the three-noun compounds. This was accomplished by extracting from each individual BNC file a sample of two-noun compounds approximating the number of three-noun compounds in that file. This procedure, in addition to ensuring

the representativeness of the sample in terms of text genres, guaranteed roughly similar sample sizes of two-adjective + multi-noun sequences.

As is well-known, adjectives come in numerous different semantic and structural types such as ascriptive vs. associative (Ferris 1993), scalar vs. non-scalar, restrictive vs. non-restrictive and non-participial vs. participial. The wealth of these distinctions coupled with the relative uncommonness of superheavy NPs left us no choice but to treat all adjectives indiscriminately.

The following constraints were imposed on the data collection. First, the compounds had to be made up of common nouns, as it is not known whether the modification patterns are the same for common and proper nouns. Second, the concordancing programme applies an orthographic criterion, and defines compounds on the basis of the number of spaces between constituents. As it treats alike morphologically simple words and compounds which are written together, all compounds with these internal "one-orthographic-slot compounds" were manually discarded from the analysis. Excluded as well were of course all those NPs in which the first adjective modified the second, as in *dark blue ball dress*. The final constraint required that all compounds be of the determinative kind, that is, exhibit a clear modifier-head structure. In fact, as copulative compounds such as *bitter-sweet* were extremely uncommon, this constraint had virtually no effect on the dataset.

Cases such as (3) above, in which a given adjective holistically modifies the entire compound, are not immediately relevant to the purpose of this study because they do not allow us to investigate the differential "visibility" of individual constituents. They were consequently put aside and assigned to the category "unclear". In any event, they occurred seldom in the data.

The modification patterns were independently determined by two native speakers of English. In case of disagreement, a third consultant was approached and the issue was decided by majority rule. If the third con-

Table 1. Quantitative survey of data

Number of nouns in compound	**Clear**	**Unclear**	**Total**
Two	560	12	572
Three	406	5	411
Four	23	4	27
Total	989	21	1,010

sultant was not entirely confident in his decision, the item was classified as "unclear". The informants were given as much context as they required for their judgement. Note that in a number of cases, alternative structural analyses were theoretically possible. Thus, what the native speakers provided was not the only possible but rather the most likely or plausible reading. Table 1 provides a survey of the data on which the present study is based.

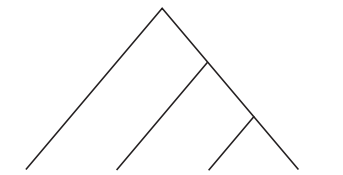
3. Data analysis

The analysis will be performed separately for each of the compound sizes. Each section is similarly organized. It begins with a discussion of the full range of theoretical possibilities of modification, moves on to formulate predictions on the basis of independently established criteria and then presents the results of the corpus analysis. The analysis begins with the two-noun NPs and proceeds to the more complex types thereafter.

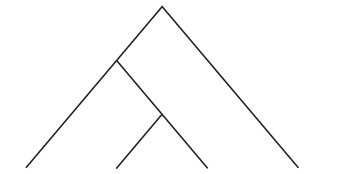
3.1. Two-adjective + two-noun NPs

On the assumption that different adjectives may modify different nouns of a compound, there are four possible types of modification in two-adjective + two-noun NPs. These are schematically represented in (9)–(12) (A = adjective; N = noun).

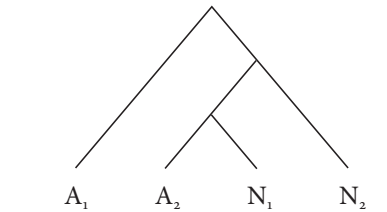
(9) Convergent head modification



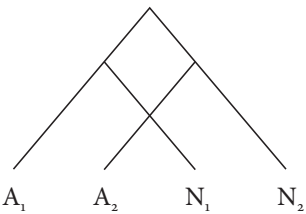
(10) Convergent modifier modification



(11) Nested modification



(12) Crossed modification



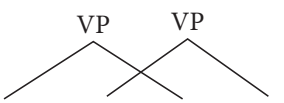
Cases (9) and (10) are labelled "convergent" because the two adjectives modify the same constituent of the compound; (11) and (12) are "divergent" because the two adjectives address the nominal constituents differentially. The difference between (9) and (10) resides in whether the two adjectives modify the head or the modifier of the compound. The two divergent types (11) and (12) are distinguished by whether the linear order of the adjectives matches that of the nominal constituents in terms of modification. In (12), there is a match in that the first adjective modifies the first noun and the second adjective the second noun. In (11), there is no such match: the first adjective modifies the second noun and the second adjective the first noun. The pattern in (11) is called "nested modification" because the representation consists of an inner and an outer shell: the association of A_2 and N_1 is nested, as it were, in the association of A_1 and N_2. The pattern in (12) is dubbed "crossed modification" because the association lines from the structural to the terminal nodes intersect.

Can one make any predictions as to the relative frequency of the various modification types? The safest prediction concerns the frequency of convergent head and convergent modifier modification. As heads are the prototypical targets of modification, they can be expected to be more frequently modified than modifiers. It is less clear whether convergent modification may be predicted to occur more (or less) often than divergent modification. If convergent modification was the rule, the task of associating adjectives with nouns would be considerably simplified for language

users. The successful association of one adjective with one noun would then be a clue for associating the other adjective with the same noun. On the other hand, the modification patterns might be governed by a principle of saturation. If a noun is modified by one adjective, it might be saturated as a modification target and hence unavailable to the other adjective.

From a theoretical perspective, crossed modification is certainly the most interesting constellation. One of the most powerful formal constraints on the well-formedness of linguistic representations is the ban on line crossing. This constraint is grounded in non-linear phonology in which units at adjacent levels are linked by association lines ensuring the integrity of multiplanar representations. Since this constraint has been applied to both phonological and syntactic representations (e.g. Goldsmith 1979, Bagemihl 1989, McCarthy 1989, Clements 1993, Halle 1995 in phonology; Lapointe 1988, Mel'čuk 1988, Kathol 2000 in syntax), it is justified to treat it as a general principle with a clear bearing on the issue of NP-internal modification. If it is regarded as a categorical constraint, a very strong prediction ensues: the complete absence of crossed modification.

However, syntactic structures have been reported to occur which are not predicted by the no-crossing constraint. A case in point is clause-final verb clusters in Dutch (e.g. Bresnan et al. 1982). Consider (13).



(13) *De mannen wilden Hans de leeuwen leren temmen.*
the men wanted.to Hans the lions teach tame
'The men wanted to teach Hans to tame the lions.'

In the linear representation, Dutch splits up the two VPs (*teach Hans* and *tame lions*) and inserts the main verb of the higher VP (*teach Hans*) between the two parts of the lower VP (*tame lions*). As the structural representation in (13) shows, this order ineluctably introduces line crossing. As Bach, Brown & Marslen-Wilson (1986) observed, language users show a preference for processing crossed as compared to nested relationships in sentences with two (and three) levels of embedding. Dutch is not the only language to document line crossing: other relevant languages include Abaza (Allen 1956), Swiss German (Shieber 1985), Old Georgian (Boeder 1995) and Chintang (Bickel et al. 2007). Further, McCawley (1982) advocates crossing lines for discontinuous structures in English, and Carnie

(2008) reviews several other syntactic processes such as gapping and raising in English which make line crossing hard to avoid unless three-dimensional representations are resorted to.

If the categorical nature of the no-crossing constraint is given up in favour of a probabilistic version, crossed modification within complex NPs may be expected to occur, though at a relatively low rate. If we extrapolate from Bach, Brown & Marslen-Wilson's results, we may predict crossed modification even to occur more frequently than nested modification.

Prior to putting these predictions to the test, let us return to the examples given in (9)–(11) and provide some context for them. The critical material appears in italics.

(14) Their last project, the Ludwig Forum internationale Kunst, opened in July 1991 in a *large converted umbrella factory* in Aachen to show contemporary art from all five continents.

(15) The Belgian state-owned Belgacom says it hopes to pick a partner by July 15 to help it develop its activities in the *digital cordless phone market*, Reuters reports from Brussels.

(16) . . . if you know you, you felt you wanted to go off and . . . start the *professional social work training* well that would probably be alright.

Sentences (14) and (15) exemplify convergent modification, with the two adjectives modifying the head in (14) but the modifier in (15). Nested modification is exemplified in (16) where the first adjective modifies the head and the second adjective the modifier of the compound.

Table 2 presents the frequency distribution of the various types of double-adjective + double-noun structures. No distinction is made between a type and a token analysis because the token/type ratio is 1 in the entire dataset. The modification types in Table 2 and subsequent tables are coded by number pairs, with the leftmost number representing the first adjective and the rightmost number the second. The numeric values identify the nominal constituent being modified (i.e. 1 stands for the first noun and 2 for the second).

It can be seen from Table 2 that convergent head modification occurs in over half of the cases (53%). This finding is as expected: convergent head modification represents the unmarked case in that the two adjectives modify the element which is most readily available to the syntactic component (i.e. the head).

Table 2. The modification rate of two-adjective + bipartite noun NPs

Modification type	Number	Percentage
Convergent head (2;2)	298	53.2%
Convergent modifier (1;1)	29	5.2%
Nested (2;1)	233	41.6%
Crossed (1;2)	0	0.0%
Total	560	100.0%

Convergent modifier modification is underrepresented in double-adjective + double-noun structures. Their low occurrence is by and large expected given that modifiers are less available for modification than heads. The fact that they occur nevertheless has to do with the acceptability of phrasal modification within English compounds (see Section 4.3).

Less expected is the relatively high share of nested modification, which occurs in more than two out of five cases. This rather high frequency is indicative of a principle of divided responsibilities, whereby the two adjectives seem to prefer separate domains of modification. Apparently, the association of the first adjective with the second noun and that of the second adjective with the first noun presents no particular challenge to language users. Given that divergent modification is only somewhat less frequent than convergent modification, it can be argued that listeners and readers cannot manage with a single parsing strategy. Their previous experience with the language does not allow them to develop a single frequency-based decoding heuristic.

Crucially, crossed modification is entirely absent from Table 2. As the database is sufficiently large to be regarded as representative of the language in general, the conclusion seems warranted that crossed modifications do not occur. This is as predicted by the categorical version of the ban on line crossing. In other words, the data do not support a probabilistic version of the no-crossing constraint.

Summing up, three factors have been found to play a role in the modification of two-noun nominal compounds by two adjectives. First, there is the preference for both adjectives to modify the head, which accounts for the majority of cases. Second, there is also a remarkable tendency for the two adjectives to have separate modification domains. This attests to a certain independence not only between the two adjectives but also between

the nominal constituents of compounds. What may explain this high frequency of divergent modification is a saturation effect. The final factor is the no-crossing constraint, which strictly prohibits the association of the first adjective with the first noun and the second adjective with the second noun. All three factors are quite strong, with the no-crossing constraint being the strongest and the other two being of similar strength. This constellation is all the more notable as the factors in question are antagonistic in nature. Whereas the head principle and the no-crossing constraint favour convergence, the saturation effect favours divergence. The combined strength of the head bias and the saturation effect explains the infrequency of convergent modifier modification. Further factors do not seem to be required to account for the empirical patterns.

3.2. Two-adjective + three-noun NPs

We now turn to the next larger structure: two adjectives preceding three nouns. There are two kinds of relationship to be considered, namely the relationship between the adjectives and the nominal constituents as well as the relationship between the nominal constituents themselves. Unlike two-noun compounds, three-noun compounds allow for different internal structures, and this variability also has to be taken into account in the analysis of the modification patterns. For expository reasons, we will begin with an examination of the modification behaviour of the two adjectives and bring the internal structure of the nouns into the picture at a later stage.

All in all, three-noun sequences allow for 9 possible types of modification: 3 convergent, 3 nested and 3 crossed. They are detailed below. (The arrow stands for "modify".)

(17) Convergent modification: $A_1 + A_2 \rightarrow N_3$; $A_1 + A_2 \rightarrow N_2$; $A_1 + A_2 \rightarrow N_1$

(18) Nested modification: $A_1 \rightarrow N_2$, $A_2 \rightarrow N_1$; $A_1 \rightarrow N_3$, $A_2 \rightarrow N_2$; $A_1 \rightarrow N_3$, $A_2 \rightarrow N_1$

(19) Crossed modification: $A_1 \rightarrow N_1$, $A_2 \rightarrow N_2$; $A_1 \rightarrow N_2$, $A_2 \rightarrow N_3$; $A_1 \rightarrow N_1$, $A_2 \rightarrow N_3$

The findings in Section 3.2 permit us to formulate the following predictions. Owing to the strength of the head principle, convergent head modification is predicted to occur most frequently while convergent modifier and middle-noun modifications will rarely occur. If a proximity effect

exists, it will foster the association between A_2 and N_1 as the only adjacent adjective-noun pair. Due to the no-crossing constraint, crossed modifications, regardless of subtype, are expected to be lacking completely. In contrast, the saturation effect leads us to expect nested modification to figure prominently in the data. Two particular subtypes of nested modification are predicted to occur as a result of the proximity principle, which favours the modification of the first member of the compound by the second adjective, viz. N_1N_3 and N_1N_2 modifications. When the proximity principle is combined with the head bias, N_1N_3 modifications may be expected to outnumber N_1N_2 modifications.

The BNC search yielded a total of 411 two-adjective + three-noun compound sequences. Recall that this is not a sample but the complete dataset. Before the presentation of the results, all types of convergent and divergent modification are exemplified in (20)–(25).

(20) In the event of an airline being involved in a major accident with one of its own aircraft, the company flight safety section will be the main liaison link between the *official national accident investigation authority* and the airline.

(21) The craftsmen of Wedgewood have ensured faithful reproduction of the original painting by the skilful application of complex ceramic colours onto a *translucent fine bone china plate*, edged with a broad band of 22 carat gold.

(22) The *English Free Church Year Book* of 1911 probably spoke for many communions when it said . . .

(23) The validity of the *lower inherited capital stock argument* (which relies on bond purchases reducing current saving and hence investment) is also called into question.

(24) Dr. Singh is currently leading a *seven-strong applied chemistry research group* at the polytechnic . . .

(25) . . . Douglas Reyburn is now firmly positioned as one of the most modern spinning mills in the business and the *largest woollen carpet yarn spinners* in the country.

Convergent modification is shown in (20)–(22), and divergent modification in (23)–(25). The two adjectives modify the final noun in (20), the middle noun in (21) and the initial noun in (22). In (23), where the three-noun structure refers to an argument about the lower stock of inherited

capital, the first and second adjective modify the second and first noun, respectively. In (24), which deals with a group of seven that does research in applied chemistry, the first adjective modifies the final noun and the second adjective the initial noun. Finally, example (25) documents a case of divergent modification in which the first adjective modifies the last noun and the second adjective the middle noun. The referent of the three-noun structure is the largest spinner using woollen yarn.

Table 3 presents the results for the three-noun structures. The rows contain all the logically possible modification types, and the columns plot the parameter "branching direction", which will be discussed separately. As in Table 2, the modification types are identified through number pairs, with the first number referring to the first adjective and the second to the second adjective. The numbers themselves identify which of the nouns is modified. Identical numbers represent convergent modification, a higher number preceding a lower number nested modification and a lower number preceding a higher number crossed modification.

Let us begin by focussing on the row totals. The most salient result in Table 3 is the complete absence of crossed modification. The cells of the three relevant rows (1;2, 1;3, 2;3) remain empty. This finding fully replicates the modification pattern of two-noun compounds.

The rows reveal another similarity between the modification of two- and three-noun compounds, namely the high incidence of nested modifi-

Table 3. The modification rate of two-adjective + tripartite noun NPs

	Branching direction						
	Left		Right		Flat		
Modification type	N	%	N	%	N	%	Total
1;1	4	19.1	17	81.0	0	0.0	21
1;2	0	0.0	0	0.0	0	0.0	0
1;3	0	0.0	0	0.0	0	0.0	0
2;1	6	85.7	1	14.3	0	0.0	7
2;2	12	92.3	1	7.7	0	0.0	13
2;3	0	0.0	0	0.0	0	0.0	0
3;1	65	47.1	73	52.9	0	0.0	138
3;2	63	90.0	6	8.6	1	1.4	70
3;3	128	81.5	29	18.5	0	0.0	157
Total	278	68.5	127	31.3	1	0.3	406

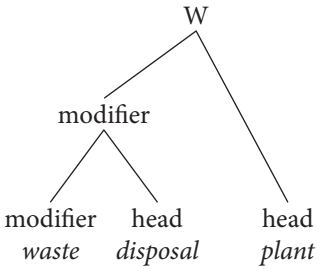
cation. While it accounted for more than 40% of cases in Table 2, it forms the absolute majority (at 53%) in Table 3 (rows 2;1 + 3;1 + 3;2). This increase is probably connected to the increased proportion of logically possible cases of divergence in tripartite noun compounds to cases of convergence in bipartite noun compounds. When the theoretical option of crossed modification is taken into account, the divergent/convergent ratio is 3:1 in tripartite vs. 1:1 in bipartite noun structures; when this option is discarded, the ratio is 1:1 in three-noun vs. 1:2 in two-noun compounds. So in either case, divergent modifications are expected to occur more frequently in the former than in the latter type of NP. As in the preceding subsection, both convergent and divergent modification are major options for language users. This finding attests to the high amount of structural freedom in the establishment of modification relations in English.

The third notable aspect of the row totals in Table 3 is that the modification behaviour of the second adjective is strikingly different from that of the first. The first adjective modifies the final noun in 365 out of 406 (or 90%) of the cases. Middle-noun modification (by the first adjective) accounts for 4.9%, and initial-noun modification for 5.1% of cases. By contrast, the second adjective modifies the first noun in 40.8%, the second noun in 20.4% and the final noun in 38.7% of cases. This distribution is more balanced than that of the first adjective. The initial and the final noun show a similarly high propensity for modification by the second adjective. This finding suggests two factors at work: one diminishing the likelihood of head modification and another increasing the likelihood of initial-noun modification. The first factor may be the saturation effect proposed in the previous subsection. When the first adjective goes on the head noun, the head bias is satisfied so that the second adjective is less attracted by the head noun and may accordingly undergo association with a different noun. The second factor is readily understood as a proximity effect which enhances the association of the second adjective and the first noun due to their adjacency. Note that the proximity effect has a very restricted domain in that it only boosts the occurrence of initial-noun modification by the second adjective. As mentioned before, the first adjective modifies the first and second noun equally often. This shows that the proximity effect is restricted to adjacency relationships.

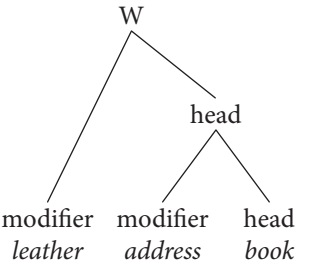
In the following, branching direction and dependency will be introduced into the picture. Basically, tripartite compounds come in two structural types. They can be left-branching or right-branching, as represented

in (26) and (27), respectively.[4] Associated with this difference in branching direction is a difference in dependency relations. Whereas a right-branching structure has two modifiers, a left-branching structure contains two heads in the terminal string. To distinguish between these two heads, the head of the overall compound will be named the major head and the head of the internal constituent the minor head.

(26)



(27)



We will not concern ourselves with the fact that Table 3 shows that left-branching compounds are significantly more frequent than their right-branching counterparts. This effect has been documented repeatedly in previous work (e.g. Warren 1978, Kutsch Lojenga 1994: 162, Krott et al. 2004). A processing explanation for this unexpected bias in a basically right-branching language such as English was developed in Berg (2012).

On the basis of Table 3, it can be shown that there is a significant effect of branching direction on modification strategies ($\chi^2(5) = 86.7$, $p < 0.001$, with the theoretical possibility of crossed modification not taken into account). This effect obtains for both the first ($\chi^2(2) = 28.7$, $p < 0.001$) and the second ($\chi^2(2) = 74.4$, $p < 0.001$) adjective. To facilitate understanding, the data in Table 3 have been rearranged according to first vs. second adjective in Table 4. The singleton case of a flat structure was discarded.

Table 4 reveals certain similarities in the behaviour of the first and the second adjective. Whereas the first noun is more frequently singled out by either adjective in right- than in left-branching compounds, the second and the third noun are singled out more frequently in the left- than in the right-branching compounds. This shared behaviour of the first and the second adjective suggests that similar factors govern their modification behaviour. What are these factors? The two major ones are depth of

[4] A third possibility, namely a flat structure, is also attested but occurs at such a low frequency that it will be neglected in the present connection. The only example in the corpus (see Table 3) is *sodium-nickel chloride*.

Table 4. The modification rates of two-adjective + tripartite noun NPs, by adjective position

Adjective position:	**First**					**Second**				
Branching direction:	Left		Right			Left		Right		
Modification type	N	%	N	%	Total	N	%	N	%	Total
First noun	4	19.1	17	81.0	21	75	45.2	91	54.8	166
Second noun	18	90.0	2	10.0	20	75	91.5	7	8.5	82
Third noun	256	70.3	108	29.7	364	128	81.5	29	18.5	157
Total	278	68.6	127	31.4	405	278	68.6	127	31.4	405

embedding and the head bias. The logic of the first factor is that the more deeply a noun is embedded in the structural representation, the closer its syntactic bond with its sister constituents, and the lower its likelihood of being modified. Conversely, the more easily a noun can be isolated from the rest, the higher its likelihood of being modified. Hence, an inverse relationship is expected to hold between depth of embedding and probability of modification. This is precisely what we find in the data. The first noun is more deeply embedded in left- than in right-branching compounds, and indeed, we observe a higher rate of first-noun modification in right- as compared to left-branching structures.

A related argument can be made for third-noun modification. The major head is more deeply embedded in right- than in left-branching compounds. It is therefore expected to be less commonly the target of modification in the former than in the latter compound type. This is what Table 4 shows for both adjectives alike.

While depth of embedding underlies the probabilistic association of first-noun modification and right-branching as well as that of third-noun modification and left-branching, the second factor, i.e. functional status, accounts for the higher rate of second-noun modification in left- than in right-branching compounds. As can be seen from diagrams (26) and (27), the middle noun serves as the (minor) head in left-branching but as a modifier in right-branching compounds (at the level of the terminal nodes).[5] We therefore expect a higher incidence of modification in the left- than in the right-branching type. Again, the data in Table 4 are in accord

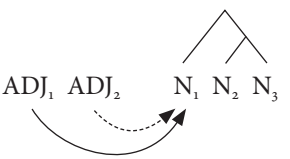
[5] Functional status at higher levels appears to have less predictive power, as the data can be satisfactorily accounted for by reference to the terminal string alone.

with this prediction, with both adjectives being sensitive to this factor. Of course, functional status also accounts for the overall preponderance of third-noun modification. Since major heads are more important than minor ones, it is only to be expected that the final noun is the typical target of adjectival modification.

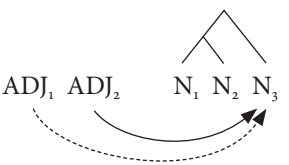
As the preceding discussion shows, there is a certain amount of "job sharing" by the functional and the structural factor. The former is responsible for the modification patterns of the second and the third noun whereas the latter is responsible for the modification patterns of the first and third noun. The reason is simply that in left- as well as in right-branching, the first noun is always a modifier and hence functional status does not vary. Similarly, the structural factor is neutralized in the middle noun, which is dominated by the same number of structural nodes in both compound types. Hence, depth of embedding is not a variable in this position.

Besides these parallels in the behaviour of the first and the second adjective, there are also significant differences between them. In the case of final-noun modification, the proportion of left-branching to right-branching cases is higher for the second than the first adjective ($\chi^2(1) = 7.1$, $p < 0.01$). At the same time, the ratio of right-branching to left-branching cases is higher for the first than the second adjective in first-noun modification ($\chi^2(1) = 5.2$, $p < 0.03$).[6] In other words, there is a tendency for the first adjective to modify the initial noun of a right-branching compound and for the second adjective to modify the final noun of a left-branching compound. In a sense, these two tendencies are complementary to each other, as revealed by the following diagrams representing the preferred options. Initial-noun modification is illustrated in (28), final-noun modification in (29). (The larger tree structure is ignored here for simplicity's sake.)

(28)



(29)



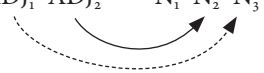
In both cases, the critical adjective modifies the structurally free constituent of the nominal compound (as represented by the solid line). These preferred patterns can thus be attributed to depth, or rather shallowness, of

[6] By contrast, no difference in the ratio of left-branching to right-branching cases is observed for second-noun modification.

embedding. Owing to the no-crossing constraint, the other adjective cannot but modify the same constituent of the compound (as represented by the dotted line).

Another difference in the behaviour of the first and second adjective concerns the modification of the middle noun. As can be gleaned from Table 4, the first adjective infrequently modifies the second noun while the second adjective does so moderately frequently. It is likely that this difference is an indirect consequence of the no-crossing constraint and the general preference for major-head modification. To see this, consider diagrams (30) and (31) below, which represent these two patterns.

(30) (moderately frequent) ADJ_1 ADJ_2 N_1 N_2 N_3



(31) (infrequent) ADJ_1 ADJ_2 N_1 N_2 N_3

Diagram (30) shows that the modification of the second noun by the second adjective (solid line) does not interfere with the predilection for major-head modification (dotted line). This nested structure can be generated without much difficulty. In contrast, the modification of the middle noun by the first adjective in (31) (solid line) leaves little room for the second adjective. If it modified the major head as the principal target of modification, association lines would cross; this option is thus not available. The only alternative for the second adjective is to modify N_1 (dashed line) and create a nested structure. This option is indeed realized, but it does not occur frequently because neither adjective goes on the major head, thereby ignoring the priority of major-head modification.

Summing up, the modification patterns of three-noun compounds have been found to be governed by a well-defined set of principles. First and foremost, crossing association lines is strictly prohibited. Second, the modification patterns are subject to a functional as well as a structural effect. Functionally, major heads are more often modified than minor heads, which in turn are more often modified than modifiers; moreover, structurally free constituents are more susceptible to modification than structurally bound elements. In addition, there is good evidence in favour of a proximity effect which establishes an association between the second adjective and the first noun. The types of influence on the three nominal

constituents of the compounds are summarized in (32) (S = structural effect; F = functional effect; P = proximity effect).

(32)

$Noun_1$	$Noun_2$	$Noun_3$
↑	↑	↑
S, P	F	S, F

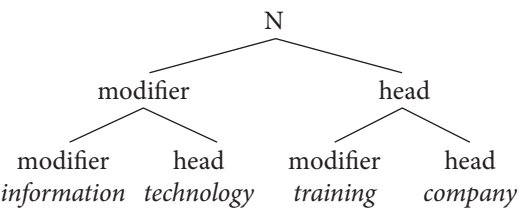
This set of facilitators generates a U-shaped frequency curve of the aggregate modification frequencies of the two adjectives, with final-noun modification being the most frequent and medial-noun modification being the least frequent option. This set also goes some way to explaining the differences in the modification behaviour of the two adjectives. Finally, an ancillary saturation effect may be necessary to account for the observation that nested modification is a major option in the data.

3.3. Two-adjective + four-noun NPs

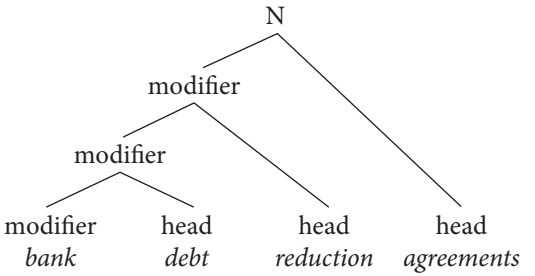
The empirical analysis will be completed by a look at how two adjectives "break into" four-noun compounds. Not surprisingly, such ultra-complex NPs occur very seldom even in written language. One might consider generating a larger sample by exploring ever larger electronic corpora. However, this was not deemed desirable because with these complex structures we are reaching the boundaries of ordinary written (or processable) language use. The uncommonness of these items should alert us to their anecdotal nature and prevent us from placing too much theoretical significance on them. In fact, their low number precludes a statistical argument.

It is useful to begin with the structural categorization of four-noun compounds. Of eleven theoretically possible structural types, four are attested in the mini-corpus. These are introduced below without any comment (for a fuller discussion, see Berg 2006). The modifying adjectives are ignored for the moment.

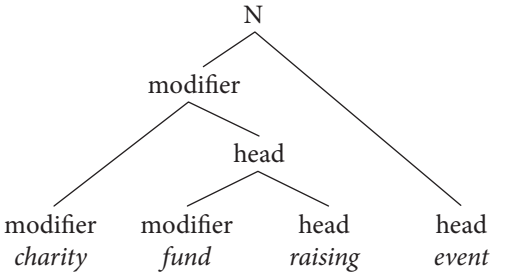
(33) Hierarchical symmetrical



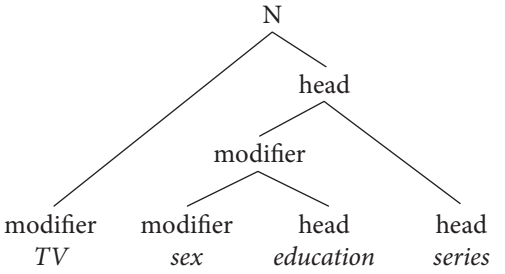
(34) Consistent left-branching



(35) Left-branching + centre-branching



(36) Right-branching + centre-branching



All in all, there are 27 two-adjective + four-noun strings in the BNC. In 23 of these, the adjectives single out individual noun constituents while in 4, they leave larger structures (consisting of more than one noun constituent) unanalyzed. Let us briefly examine the latter 4 cases more closely. They are remarkably homogeneous, in that in each of them, the first adjective identifies an individual noun (i.e. the major head) whereas the second adjective modifies two nouns together, and specifically, the first and the second noun. There are no cases where both adjectives modify partly the

same constituents, with, for instance, the one adjective modifying the single noun X and the other adjective modifying the larger structure (XY). Among the four cases in question is (37).

(37) ((Proper name)) has sold . . . Integrated Cached Disk Array storage devices to Delta Air Lines.

In this example, the adjective *Cached* modifies *Disk Array* as a unit rather than either of its constituents alone. There is one possible explanation for why it is the second rather than the first adjective that modifies two constituents at the same time. As will be shown later, the initial adjective almost always modifies the major head of four-noun compounds. As typical targets of modification, heads need to be clearly identifiable; this requirement is met when a neat distinction between major heads and the other constituents can be drawn (see Marelli, Crepaldi & Luzzatti 2009). By contrast, non-heads need not be distinguished as neatly, given their reduced capacity to project their features to higher levels.

We now proceed to an analysis of those compounds whose constituents were individually modified by the attributive adjectives. In 22 out of 23 cases, the first adjective modifies the major head of the compound. The only exception is a sequence in which the first adjective modifies the second noun and the second adjective the first. The almost exclusive focus of the first adjective on the major head severely reduces the range of possible modification patterns, which are displayed in Table 5.

Closer inspection of Table 5 reveals a distribution that is largely as expected. There are four modification types, with 4;4 being the most fre-

Table 5. The modification rates of two-adjective + four-noun NPs

	Structural type				
Modification type	HS	CL	LC	RC	Total
2;1	0	1	0	0	1
4;1	1	3	1	1	6
4;2	2	1	0	0	3
4;4	4	5	3	1	13
Total	7	10	4	2	23

Note: HS = hierarchical symmetrical; CL = consistent left-branching; LC = left-branching + centre-branching; RC = right-branching + centre-branching

quent, 4;1 less frequent, 4;2 even less frequent and 2;1 least frequent (and 4;3 non-occurring). The major head is most often singled out by both adjectives together (4;4), whereas the middle constituents of four-noun compounds are rather impervious to modification. The intermediate frequency of initial-noun modification by the second adjective suggests a proximity effect which is, however, weaker than the head effect. This result replicates the U-shaped distribution observed in the previous subsection (3.2), with final-noun modification being the most frequent.

Like the less complex patterns, the four-noun compounds do not show a single case of crossed modification. Unfortunately, the numbers in Table 5 are way too low to reliably gauge the effect of structural type on the modification patterns.

To sum up, the four-noun compounds disclose a strong head effect. Both the first and the second adjective exhibit a preference for major-head modification, but this preference is much more pronounced in the case of the first than of the second adjective. This leads to a (slight) predominance of convergent modification. Violations of the no-crossing constraint do not occur in the data. The only other factor that appears to influence the modification patterns is a proximity effect, which facilitates the modification of the initial noun by the second adjective.

3.4. Conclusion

There is a high degree of consistency in the data. The modification patterns of all NPs, irrespective of their size, are shaped by the same set of principles. The most powerful constraint is the ban on crossing association lines, which applies without exception. The second most important constraint is the preference for major-head modification. This functional principle is supplemented by a structural one whereby depth of embedding correlates negatively with modification rate. (Note, however, that there were too few data points in the four-noun compound set to show the generality of this principle.) Rather strong support was found for the proximity principle, which facilitates the modification of the first noun by the second adjective. The rate of convergent vs. divergent modification is relatively similar across compound size. The fact that divergent modification is strongly represented in the data argues for a saturation effect, which lowers the probability of convergent modification. The analysis of the three-noun compounds suggests a U-shaped frequency effect, with the final noun most often, the

initial noun less often and the middle noun least often modified. In four-noun compounds, the third noun is less often modified than the second. While there are too few relevant items in the set of four-noun compounds for a statistical argument, all of them are compatible with the claims made for the smaller compounds.

4. Theoretical discussion

This theoretical discussion is divided into three parts. We begin with a comparison of the modification behaviour of single-adjective and double-adjective NPs. Subsequently, we turn to a general account of the empirical data and finish with a close-up of the no-crossing constraint.

4.1. Comparing the modification behaviour of single and double adjectives

The introductory section drew attention to a previous study which investigated how nominal compounds are modified by single adjectives. A brief comparison of single- and double-adjective NPs is therefore in order. Generally speaking, we would expect the single-adjective modifications to be influenced by the same factors that operate in double-adjective modifications. Indeed, this is what we by and large find. The head preference principle is a strong determinant in both data sets; depth of embedding plays a comparatively smaller part, but can clearly be seen to be at work in the two datasets. Obviously, the no-crossing constraint is inapplicable in the single-adjective data, so the two data pools cannot be compared on this score. The same goes for the saturation effect.

The only point of contrast is created by the proximity effect, which plays a minor role in the single-adjective set but a major role in the double-adjective set. There is a rather straightforward explanation for this difference. In the single-adjective data, the proximity effect and the head bias vie for the same adjective, with the former factor favouring modifier modification and the latter head modification. As the data of the earlier study indicate, the head bias outweighs the proximity effect. In the double-adjective class, however, less competition is generated between the proximity effect and the head bias for the simple reason that the two factors may operate on different adjectives. To be specific, the first adjective usually satis-

fies the head modification preference while the second adjective highlights the proximity effect. In light of this, it may be argued that the proximity principle is always present but that it is overshadowed by the head bias in single-adjective modifications.

In addition to the question of whether single- and double-adjective modification are subject to the same constraints, it is worthwhile exploring how the single adjective in the one modification type compares to the two adjectives in the other. More specifically, does the single adjective behave more like the first than the second adjective in double-adjective modification? The answer appears to be in the negative. The single adjective behaves like the first adjective in the double-adjective data in some respects but like the second adjective in others. For example, a strong preponderance of (major) head modification is shared by the single adjective as well as the first adjective in the double-adjective NPs. In other respects, it is the behaviour of the second adjective that resembles that of the single adjective. The second adjective modifies the first and the last noun at approximately the same high frequency while middle-noun modification is appreciably less common (see Table 4, above). A similar distribution emerges in single-adjective + three-noun sequences, with the final noun being most frequently, the initial noun less frequently and the middle noun least frequently modified. The same similarity in the behaviour of single adjectives and second adjectives can be seen in four-noun compounds. Concluding, single adjectives can be equated neither with first nor with second adjectives in NP-internal modification. They share properties with both, probably because they are structurally similar to both: the single adjective is positionally similar to the first adjective; at the same time, it is also similar to the second adjective in that both are contiguous to the first noun in the NP.

4.2. Modification in a theory of accessibility

The claim to be put forward in the present section is that the probability of adjectival modification is a function of the accessibility of the nominal constituents of a compound: the higher their accessibility, the more likely they are to be modified by adjectives. All principles that shape the empirical data affect accessibility and can therefore be accommodated within the same framework.

Almost by definition, heads are more accessible than non-heads because of their ability to make their features available to the lexical level. It is at

this level that a relationship can be established most easily with adjectives, which are, of course, also lexical units. This explains the preponderance of major-head modification across all compound sizes. Minor heads are less accessible than major heads but more accessible than modifiers. Thus, the availability of the nouns in compounds is a scalar rather than an all-or-none phenomenon. The reduced availability of modifiers can, however, be compensated for by other principles (see below).

Accessibility is also influenced by depth of embedding, in that the more deeply a constituent is embedded, the lower its accessibility. Keeping in mind that it lies in the nature of modification to identify one particular constituent against the background of others, it can be assumed that this election process is all the easier, the greater the structural independence of a given constituent. Elements that have a relatively independent status in the overall structure therefore have a higher accessibility than those which are more tightly interwoven with others.

Whereas depth of embedding is a hierarchical principle, proximity is a linear factor. As the representation of language is both hierarchical and linear in nature, it comes as no surprise that the two effects are required in an account of the empirical data. The proximity principle implies an increased accessibility of the first noun at the moment the second adjective selects its modification target, simply because the adjective and the noun are adjacent, or more generally, at the time the second adjective is produced, the next element in line needs to be highly available because it is about to be produced. The relatively large number of initial-noun modifications is especially striking in the light of the fact that the first noun in a compound is invariably a modifier and hence of low accessibility. This functional weakness is offset by the proximity principle.

We now apply these claims to divergent modification and begin by recalling that the divergent type occurs approximately as often as the convergent type across all compound sizes. The high rate of divergent modification is solely brought about by nested modification because line crossing (which would also count as divergent modification) does not occur. Nested modification receives the following interpretation from the viewpoint of accessibility theory. Once a nominal constituent has been singled out by one adjective, its accessibility is reduced such that it is less available to the other adjective. As a consequence, the other adjective is more likely to modify a different noun. The reduced availability of a modified noun is assumed to underlie the saturation effect.

This explanation is less far-fetched than it might seem. It is well-known from research in language processing that linguistic units undergo self-inhibition after production, i.e. they are temporarily unavailable after having been used (e.g. MacKay 1987). Although modification and production are not exactly the same, they are both selection processes. The selection of output units for production operates on principles similar to the selection of a target for modification. Both select one unit from among a set of competitors and both select the most accessible unit at a certain moment in time. Critically, both exhibit a similar after-effect: inhibition in the one case and saturation in the other.

Note that the proximity principle and the saturation effect make rather similar predictions. For two-noun compounds, their predictions are even identical. The two effects enhance the modification of the first noun in that the proximity effect encourages the association of the contiguous adjective and noun, and the saturation effect leads to the association of the second adjective with the first noun after the first adjective has gone on the head noun (viewed from a left-to-right perspective). For three-noun compounds, however, the predictions are slightly different. While the proximity effect operates as described before, the saturation effect may promote the association of the second adjective with either the first or the second noun. What we observe in the empirical data (see Table 4) is a higher involvement of the first than the second noun in the modification process. This may be taken to suggest that the proximity effect is a better predictor than the saturation effect. However, care should be exercised in not dismissing the saturation effect too quickly. This factor predicts an equal involvement of the first and the second noun only if no other factors are involved, which is not the case. It thus seems premature to rule out its existence at this stage of enquiry. It will be left to future research to enquire whether the proximity principle renders the saturation effect otiose.

4.3. Explaining the absence of crossed modification

This final subsection aims to deepen our understanding of the complete absence of crossed modification from the corpus. The easiest way to deal with this empirical finding would be to view it as an effect of the no-crossing constraint and leave it at that. The no-crossing constraint has one strong point in its favour: as a categorical constraint, it provides a perfect fit to the data. Unfortunately, it suffers three major weaknesses. To begin with, like

all formal accounts, it translates a given observation into another (possibly more precise) language without, however, explaining the empirical facts (Givón 1979). The origin of the constraint itself remains obscure. In other words, the constraint is an explanandum rather than an explanans. What is more, the theoretical status of the no-crossing constraint is highly uncertain. Coleman & Local (1991) drew attention to the distinction between mental (linguistic) representations and pictures of these on paper and argued that if the target of investigation is the former, this constraint is either redundant or no constraint at all. Finally, as has been shown in Section 3.1, the no-crossing constraint can be violated. This makes it difficult to derive clear predictions from it. As an inviolable constraint, it makes categorical predictions, but as a violable constraint, it makes probabilistic predictions (and of course, no predictions if it is no constraint at all). To determine which type of prediction is appropriate in any given case requires a theory detailing under which circumstances line crossing is or is not allowed (and why). However, no such theory has so far been developed. All these shortcomings cast serious doubt on the ban on crossing association lines as an explanatory principle. We therefore have to look beyond the no-crossing constraint itself and examine the factors that prevent the crossing of association lines.

The following argument will be developed in two steps. The first part discusses the factors which hinder the violation of the no-crossing constraint. However, as these factors do not categorically eliminate such violations, a more powerful mechanism has to be invoked which can come to grips with the complete absence of crossed modification. This mechanism does not, however, make the other factors superfluous.

In combination, the head preference and the proximity effect strongly discourage crossed modification. When the first adjective modifies the major head of the compound, association lines cannot possibly cross. All modifications that the second adjective contracts must then be either nested or convergent (on the head). We therefore need to understand why the first adjective is much more likely to modify the head than the second. The reason is that the vast majority of NPs have only one adjective (if they have one at all). Listeners have been shown to employ probabilistic, frequency-sensitive decoding strategies and to begin processing immediately upon perceiving the input (Marslen-Wilson & Tyler 1980). When they hear the first adjective, they are nudged into interpreting it as the only one. They are thus likely to associate the first adjective with the head of the complex NP in much the same way as they associate a singleton adjective with the

head of the compound or a simple noun. Of course, they are capable of reanalysis, but this is a time-consuming and costly process.

When this bias of linking up the first adjective with the compound's head is combined with the proximity principle, the crossing of association lines is impossible. In the light of the empirical data, this is a welcome result. However, the preference for head modification and the proximity principle are probabilistic biases, not deterministic laws. Both modifier modifications and non-adjacent modifications are attested in the data. The probabilistic nature of the two factors has a critical consequence: these biases are perfectly able to predict the uncommonness of crossed modification, but they fail to explain its total absence. To put it differently, they predict its occurrence, however rare it may be. Therefore, a stronger mechanism is required which rules out crossed modification altogether.

To understand why line crossing does not occur at all, it is helpful to return to Liberman & Sproat's (1992) distinction between syntactic and morphological modification. Rephrasing the results of the empirical analysis in terms of this distinction, we can observe that syntactic modification always precedes morphological modification in the NP (see (16), (24) and (25) above). Morphological modification always occurs with adjectives that are closer to the first noun than with those adjectives involved in syntactic modification. Importantly, if association lines crossed, we would have morphological modification precede syntactic modification. The reason for the ban on crossing association lines may now be argued to reside in the categorical avoidance of morphological-before-syntactic modification.

Why is this modification order so strictly avoided? It is common wisdom that morphological and syntactic units differ in scope. Morphology takes place within word boundaries whereas syntax takes place within phrase (or larger) boundaries. When an adjective partakes in morphological modification, it forms part of a compound whose boundary falls to the left of the adjective. This structure allows further adjectives to the left of this adjective to undergo syntactic modification because this modification type occurs at a higher hierarchical level and thus does not interfere with morphological modification. In this way, the scopal difference between syntax and morphology is respected.

If, however, syntactic modification followed morphological modification, syntactic scope would be narrower than morphological scope. A syntactic relationship would be actualized within the confines of the word because the word boundary would be to the left of the adjective undergoing

morphological modification. This implies not only the destruction of the lexical integrity of the word but ultimately the abolition of the hierarchical organization of language. The occurrence of the syntactic-before-morphological order (and the non-occurrence of the morphological-before-syntactic order) can now be understood as a preference to abide by the principle of hierarchical organization. The fact that this principle is never compromised in the modification patterns testifies to its overall importance in guaranteeing the proper functioning of language as a layered system.

However plausible this account may seem, it is challenged by the occurrence of so-called phrasal compounds (see, for instance, Lieber 1992 from whom the following examples have been taken; see also (4) above).

(38) a. the Charles and Di syndrome
b. a slept all day look
c. God is dead theology

Different types of syntactic material function as modifiers in these compounds: an NP in (38a), a VP in (38b) and a full sentence in (38c). These examples leave little doubt that English tolerates the confusion of levels dismissed above. Thus, the infiltration of morphology by syntax is not categorically excluded. Why, then, is phrasal compounding allowed but crossed modification disallowed? The answer is that the intermingling of syntactic and morphological information has different effects in the two structures. It leads to a processing difficulty in the case of phrasal compounds but to a processing breakdown in the case of crossed modification. Let us begin with the latter. Because of the lack of inflections on adjectives, English cannot formally distinguish between syntactic and morphological modification. It therefore has to rely on word order to mark the two types of modification. If crossed modification was acceptable, listeners and readers could not discriminate between nested and crossed modification on the basis of word (and morpheme) order. In actual fact, they would not know how to deal with crossed modification. When association lines are interpreted as encoding linear order (as argued by Sagey 1988 and Hammond 1988), the crossing of association lines would generate contradictory information about serial order (both XY and YX). This unwelcome situation precludes the reliable working-out of modification relationships. Therefore, crossed modification is not allowed.[7]

[7] It might be argued that in the absence of formal clues, listeners and readers may draw on semantic information in order to work out the modification patterns. Apparently, semantic

The mixture of syntactic and morphological information in phrasal compounds certainly poses a processing difficulty, though not an insurmountable one. Although, to the best of my knowledge, the processing of phrasal compounds has not been investigated in any detail, it seems clear that language users are well able to analyze them, that is, they can divide the compound into its head and its modifier even though the latter is complex. Since a thorough analysis of how this is accomplished is beyond the scope of the present article, a few hints must suffice. Among the strategies that listeners and readers are likely to employ are the following: when they come across an initial verb, as in (38b), they construct a VP; when a verb is preceded by a noun, they generate an S node, as in (38c); and when they hear a conjunction preceded by a noun, as in (38a), they create an NP. These syntactic nodes are subsequently integrated into the compound. Irrespective of whether listeners and readers proceed in precisely this way, it may be argued that the processing system is powerful enough to tolerate the interspersing of morphological with syntactic information as long as the two can be kept apart. This is the case in phrasal compounds, which are therefore licit, but not the case in crossed modifications, which are therefore illicit.

5. Conclusion: Looking behind the scenes of the no-crossing constraint

In this article, an attempt has been made to show that a formal principle such as the no-crossing constraint can be motivated in functional terms. The syntactic head principle, the iconic proximity principle and especially the iconic syntax-before-morphology ordering principle bring about the no-crossing constraint. These principles are eminently functional because they supply the listener with decoding strategies in everyday communication (as well as supplying the speaker with encoding strategies). Note that these strategies are required independently of the existence of the formal constraint.

information is too unreliable to make up for the absence of formal marking. While it may be helpful in some cases, there are others where the semantics would permit the adjective to be involved in both morphological and syntactic modification. As this ambiguity cannot be resolved as a matter of principle, crossed modification is no option.

This functional explanation presents the no-crossing constraint in a new light. This constraint does not actively prohibit crossed modification, but merely states in formal terms, and thereby reflects the fact, that crossed modification does not occur. It is a geometrically based label, not a causal agent. Although it does provide an accurate characterization of the empirical patterns, it has hardly any explanatory power.

It might appear paradoxical that the no-crossing constraint is so eminently successful as a descriptive device but at the same time inadequate as an explanatory principle. In this respect, two related questions need to be posed. Why is there such a close match between the predictions of this constraint and the empirical patterns, and why is there such a close match between the formal and the functional principles? Both questions can be answered by one underlying explanation. The association lines of the no-crossing constraint as applied to the modification data put us on the right track. They depict the scope of modification. Hence, an intersection of association lines describes an interference between, and eventually the destruction of, different scopal relations. This is the functional explanation for the absence of crossed modification in the data.

This analysis may help us to better understand why the no-crossing constraint is inviolable in some cases but subject to violation or even non-existent in others. When it is inviolable, it captures the effects of functional principles very well. When it is violable, it does so less well, and when it is non-existent, it does not do so at all. To illustrate the lattermost case, consider co-reference in complex sentences.

(39) The better Daniel gets to know Liza, the more he likes her.

(40) The more Daniel phones Liza, the less she wants to speak to him.

Sentence (39) exemplifies crossed co-reference, and (40) nested co-reference. Despite its crossed reference, sentence (39) is at least as natural as (40). This suggests quite strongly that the no-crossing constraint is inoperative in co-reference. Why should this be? One possible solution is to argue that the no-crossing constraint is syntactic in nature while co-reference relationships may be mainly established by non-syntactic, in particular semantic mechanisms. In fact, it has transpired from research into

agreement patterns that agreement markers may be selected on the basis of syntactic or semantic criteria. Crucially, the further the target is from the controller, the higher the probability of semantically driven agreement (e.g. Nixon 1972, Corbett 1983, Panther 2009). Thus, semantics is responsible for long-distance relationships whereas syntax is the decisive criterion in short-distance relationships. As the above examples of co-reference represent long-distance (i.e. between-clause) effects, it makes good sense to claim that co-reference relationships are grounded in semantics. The (to my mind) uncontroversial assumption that the no-crossing constraint has no semantic basis now furnishes an explanation for the observation that co-reference is unaffected by this constraint.

The validity of this analysis of cross-clausal co-reference can be tested by transcending sentence-based syntax and entering the realm of discourse. If, as argued above, the prohibition on line crossing is a relatively short-distance syntactic effect, it may be predicted to be unknown in conversation where two (or more) interlocutors refer to each other's utterances over a number of turns. This prediction is strikingly borne out. In a highly significant article, Levinson (2013) demonstrates not only the generality of centre-embedding but also the generality of line crossing in spoken discourse. It may be inferred from this result that the no-crossing constraint has no pragmatic basis. It is more adequately conceived of as a local, probabilistic and functional rather than a formal principle.

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