The modification of compound nouns by three adjectives

Thomas Berg
University of Hamburg

This paper is the final instalment in a series of studies investigating the modification patterns in complex noun phrases (NPs) in English. It particularly focuses on the modification of two-noun compounds by three attributive adjectives. An analysis of all such NPs from the BNC reveals a strong preference for head modification over modifier modification, similar rates of convergent and divergent modification and the non-occurrence of crossed modification. The single most important factor influencing the modification patterns is functional status. The larger the number of adjectives modifying the head of the compound, the higher the frequency of the modification type (modulo a proximity effect). The absence of crossed modification is expected under the no-crossing constraint, which is understood here not as a formal but as a functional principle ensuring successful communication. The various factors can be tied together under the rubric of accessibility. The probability of selecting a particular modification target is argued to be a function of the accessibility of the nouns in an NP.

1. Introduction

This study represents the third part of a trilogy of investigations into the complexities of adjectival modification of nominal compounds (Berg 2011, 2014). The special interest of these modification patterns derives from an extraordinary twist of English, which allows adjective-noun sequences as constituents of compounds.1

1. Bell (2011: 146) contests this generally accepted claim, contending that the nouns in a compound “cannot be modified independently of one another”. She does not deny the well-formedness of examples such as red tulip collection, but argues that red tulip is not a phrase but a compound. Even if this was true, the fact remains that red modifies tulip independently of collection. Moreover, Bell’s more general claim that phrases cannot occur inside compounds is flatly contradicted by the existence of phrasal compounds (see Lieber 1992 and Section 6.2 below). The sequence red tulip is a phrase which is associated with collection to create the complex compound.
These cases contrast in an intriguing way with nominal compounds modified by an attributive adjective. Compare (1) and (2) which somewhat unconventionally combine structural and functional information because both constituency and dependency play a role in the modification process.

Superficially speaking, (1) and (2) display the same A-N-N sequence. However, while the adjective *sparkling* in (1) modifies the non-adjacent head of the compound or rather the entire compound, the adjective *erotic* in (2) modifies the adjacent noun *art*. This gives rise to a left-branching structure in (2), but a right-branching structure in (1). Importantly, as indicated by the arrows, the modification in (1) is compound-external, whereas that in (2) is compound-internal. As (1) is a phrase (i.e. a syntactic object) and (2) a compound (i.e. a morphological object), (1) represents a case of syntactic modification and (2) a case of morphological modification (compare Liberman & Sproat 1992: 133).

Syntactic modification between an adjective and a noun may legitimately be regarded as the unmarked option. Adjectives typically modify nominal heads, no matter whether the noun is morphologically simple or complex. In fact, syntactic modification is the only permissible option in many languages. It is a remarkable fact that English is less constrained in also allowing morphological modification, which has been repeatedly discussed in the pertinent literature (e.g. Ackema & Neeleman 2004; Alegre & Gordon 1996; Bauer 1978; Carroll 1979).

There are two methods we may apply in order to delve more deeply into the structural and functional relationships governing adjective-noun sequences. Either the size of the compound or the number of adjectives may be increased. Of course, both directions could be followed simultaneously, but the analytical task is simplified when one factor is examined while the other is held constant.

2. Since the focus of this article is on individual constituents rather than higher-order units, we will somewhat loosely say that adjectives modify the head rather than the modifier although it would in some cases be more accurate to say that they modify the entire nominal compound.
The first direction was tried in the initial part of the trilogy (Berg 2011), which systematically increased the number of nominal constituents of compounds from two to three to four by capitalizing on the possibilities offered by recursion. The guiding question was whether cases (1) and (2) exhaust the possibilities of modification in English or whether the (single) adjective can also contract a long-distance relationship with a middle constituent in three- and four-noun compounds. No constituent of a compound, irrespective of the size of the latter, was found to be immune to modification by a preceding adjective. The following examples involve three-noun compounds. The adjective modifies the final noun in (3), the middle noun in (4) and the initial noun in (5).

1. trained air traffic controllers
2. transnational drug trafficking case
3. inner city task forces

Berg (2011) observed that the frequency with which the individual parts of compounds were singled out varied widely. Two main factors were argued to account for the empirical data – a structural and a functional one. The latter makes heads more susceptible to modification than modifiers while the former makes less deeply embedded constituents more prone to modification than more deeply embedded ones.

The second direction was tried in the midsection of the trilogy (Berg 2014), which raised the number of premodifying adjectives from one to two while looking at the same range of compound sizes as in the previous study. Obviously, the occurrence of two adjectives greatly increases the number of logically possible modification types. There are four types in two-noun compounds, nine basic types in three-noun compounds and sixteen basic types in four-noun compounds (disregarding variation in the internal structure of the more complex nominal compounds). To be specific, the two-noun compounds preceded by two adjectives allow for the following logically possible modification types (descriptive labels in double quotes): (i) both adjectives jointly modify the head of the compound (“convergent head modification”); (ii) both adjectives jointly modify the modifier of the compound (“convergent modifier modification”); (iii) the first adjective modifies the head and the second adjective the modifier (“nested modification”); and (iv) the first adjective modifies the modifier and the second adjective the head (“crossed modification”). The first three modification types are exemplified in (6)–(8).

1. nascent new world order
2. Annual General Meeting date
3. inadequate nuclear waste handling
Again, it could be shown that the different modification types varied strongly in frequency. While convergent head and nested modification were quite common, convergent modifier modification was uncommon. Crossed modification did not occur at all, i.e. the right-hand adjective never modified a nominal constituent which was further to the right of the constituent which had been modified by the left-hand adjective. This observation is reminiscent of the no-crossing constraint of autosegmental phonology (e.g. Goldsmith 1976) and syntax (e.g. Carnie 2008). That is to say, the association lines linking adjectives and nominal constituents do not intersect. Furthermore, in addition to the structural and the functional factors referred to above, the empirical data could be shown to be sensitive to a proximity constraint which promoted the modification of adjacent elements, that is, of the first nominal constituent by the (adjacent) rightmost adjective. All in all, there was a great deal of consistency between the results of the first (i.e. single-adjective) and the second (i.e. double-adjective) investigation.

The present study follows up on the second investigation by increasing the number of attributive adjectives from two to three. However, this increase necessitates keeping the complexity of the nominal compound to a minimum. Three adjectives are only rarely found to modify compounds consisting of three or more nominal constituents. The analysis was therefore confined to two-noun compounds.

This heightened number of premodifying adjectives raises both old and new issues. Of course, the overall question remains the same: what qualitative and quantitative patterns do the empirical data fall into? A second question is whether the same factors are in evidence that were found to determine the modification patterns in single- and double-adjective NPs. As in the double-adjective investigation, it will be asked whether the adjectives gravitate towards convergence or divergence, i.e. whether they tend to modify the same or different nominal constituents. The following questions also have to be answered. Is the no-crossing constraint to which double-adjective NPs are subject also in place in triple-adjective NPs? And if so, what underlies this ban on crossing association lines? Novel questions raised by the design of this study focus on the behaviour of the three attributive adjectives. Does the serial position of an adjective influence its choice of target of modification? To be more specific, does the proclivity to head modification increase or decrease as we go from the first to the second to the third adjective? Does the number of adjectives that jointly modify a nominal constituent predict modification rate? Since there are only two nominal constituents but three adjectives, two adjectives must jointly modify one noun. Is the head or the modifier the preferred locus for joint modification? A comparison also suggests itself of the double- and triple-adjective NPs. Finally, the empirical data have to be integrated into a compound model of single and multiple modification. These and related issues will be taken up in this paper.
2. Survey of logically possible modification types

A survey of all logically possible modification types will serve as a useful background against which the empirical data to be examined below can be compared. The constellation of three prenominal adjectives and a two-noun compound gives rise to a total of eight potential modification types, which are listed in (9)–(16) (A = adjective; N = nominal constituent of compound; subscripts indicate position).

(9) $A_1 \quad A_2 \quad A_3 \quad N_1 \quad N_2$ convergent head modification

(10) $A_1 \quad A_2 \quad A_3 \quad N_1 \quad N_2$ convergent modifier modification

(11) $A_1 \quad A_2 \quad A_3 \quad N_1 \quad N_2$ divergent head modification

(12) $A_1 \quad A_2 \quad A_3 \quad N_1 \quad N_2$ divergent modifier modification

(13) $A_1 \quad A_2 \quad A_3 \quad N_1 \quad N_2$ crossed modification I

(14) $A_1 \quad A_2 \quad A_3 \quad N_1 \quad N_2$ crossed modification II

(15) $A_1 \quad A_2 \quad A_3 \quad N_1 \quad N_2$ crossed modification III

(16) $A_1 \quad A_2 \quad A_3 \quad N_1 \quad N_2$ crossed modification IV
According to the interrelationships of the association lines, this classification system distinguishes three types of modification – convergent, divergent, and crossed. There are two types of convergent and divergent modification each and four types of crossed modification. Diagram (9) illustrates convergent modification of the head of the compound, (10) convergent modification of the modifier. In the case of divergent modification, two adjectives modify one nominal constituent and one adjective the other. If the head is modified by two adjectives, these must be the initial two (unless association lines are crossed); if the modifier is modified by two adjectives, these must be the final two. The former constellation is termed divergent head modification and shown in (11), the latter is dubbed divergent modifier modification and shown in (12). The difference between (11) and (12) thus lies in whether the middle adjective goes on the head or the modifier of the compound. The remaining options (13)–(16) capture the four types of line crossing. These will not be given a detailed description beyond a single comment to the effect that one line is crossed in (13) and (14) while double-line crossing occurs in (15) and (16). Note also that crossed modification is always divergent modification. What predictions can be formulated regarding the frequency of these types will be examined in the next section.

3. Predictions

Let us now turn to the predictions that can be derived from previous work. Aprioristically, convergent modification would seem easier to implement than divergent modification. This follows naturally from the reasoning that the three adjectives are given a uniform treatment in convergent modification, but have to be individually handled in divergent modification. However, the earlier double-adjective + two-noun compound analysis revealed a percentage of divergent modification as high as 41.6%. In view of the fact that three adjectives offer two types of divergent modification (11)–(12) compared to only one in the case of two adjectives, it may be predicted that divergent modification should play an important role in the data. In the two prequels, heads were found to be the preferred modification targets. Thus, head modification, be it convergent or divergent, can be expected to outstrip modifier modification. Furthermore, no major difference is predicted between convergent and divergent head modification. This is because convergent modification was well represented in the two-adjective study and because there is a high degree of overlap between the two modification types (i.e. the first and the third adjective behave alike).

As noted above, we also have to reckon with a proximity effect, which encouraged the association of the second adjective with the first nominal constituent in
double-adjective + compound sequences. Extrapolating to triple-adjective + bipartite compound NPs, we may predict an elevated rate of divergent head modification. This modification type provides for a unique association of the only pair of adjacent elements from non-identical word classes (i.e. the third adjective and the first nominal part of the compound). The other modification types do not directly profit from the proximity effect because of the greater distance between adjectives and nouns.

Crossed modification was found to be absent from the corpus of double-adjective + nominal compound NPs. It is thus to be expected that the same result emerges in the present study. The number of adjectives is highly unlikely to influence the possibility of line crossing. After all, line crossing is widely understood to be a principle of general validity. This expectation makes it futile to speculate on the probability of occurrence of the different types of crossed modification listed in (13)–(16) above.

To conclude, the following predictions regarding the rate of the various modification types can be made. Convergent and divergent head modification are expected to be the most frequent modification types. An advantage accrues to convergent head modification from the fact that the head is the modification target for all three adjectives. At the same time, divergent head modification is favoured by the proximity principle. Since it is not known which of the two factors is the more important one, it is difficult to predict a rank order for these two modification types. Divergent modifier modification may be predicted to outweigh convergent modifier modification because the former type targets the head once while the latter ignores the head altogether. It should be noted that this prediction stands on less than firm ground because the bias in favour of divergent modifier modification might be counteracted by an inherent edge of convergent over divergent modification (as observed in the two-adjective study). Finally, crossed modification is predicted to be the least common type of all.

4. Data sampling

Since three-adjective + two-noun compound sequences are rather infrequent in general language use, it was decided to extract all relevant items from the British National Corpus (BNC World), an electronic database comprising approximately 100 million words. By today’s standards, the BNC cannot be considered large. However, because the data fall into a fairly low number of categories and because the main empirical points to be made in this paper come out quite clearly, it was deemed unnecessary to enlarge the database.

The search term “&aj? &aj? &aj? &NN? &NN?” was devised so as to restrict the yield to common nouns because it is doubtful that proper nouns are modified
in exactly the same way as common nouns. The search returned 917 hits which were subjected to a rigorous filtering procedure. The following five reasons led to a massive reduction of the original dataset.

Firstly, all adjectives obviously had to modify either of the nominal constituents. When an ostensible adjective (i.e. a word tagged as adjective) modified another adjective rather than the nominal compound, the item was discounted. In (17), royal modifies blue and hence assumes an adverbial function. The critical parts are italicized.

(17) Inside the box … was a folded royal blue cashmere jersey.

Secondly, it has to be borne in mind that the automatic search operates on written representations. Words that are written solid are treated by the concordancing programme as single units even though they may consist of two lexemes. The search term thus also returns three-noun compounds. These cases were eliminated because the analysis was limited to two-noun compounds.

Thirdly, some adjectives were internally complex, that is, they were compounds themselves. These compounds may be made up of different word classes, as shown in (18).

(18) The best solution is to buy a special low-power electric pond heater…

The adjective-noun structure of low-power in (18) renders the lexical status of this compound somewhat equivocal. All such cases were discarded. However, cases in which adjectives were themselves modified by an adverb were retained because this ADJP-internal modification was felt to be independent of the NP-wide modification at issue here.

Fourthly, the logic of the study necessitates a certain autonomy of the two constituents of the compounds because each constituent must have the chance of being modified individually. However, this is not always so. In some cases, the union of the two constituents is so close that the adjective modifies the compound as a unit rather than one of its constituent parts. Consider (19).

(19) …Hypermedia objects and documents are stored using a simple distributed persistent storage device.

Here, the adjectives do not have the choice of modifying either storage or device. They rather function as modifiers of the entire compound. Being orthogonal to the aims of this study, these cases were left out of account.

Fifthly, an attempt was made to secure the basic independence of the compound constituents from the prenominal adjectives. If this independence is not

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3. This search ignores strings containing commas.
given, the adjectives do not even stand a theoretical chance of modifying either constituent. This criterion was implemented by making sure that the compound can stand on its own. This was confirmed by a Google search. If the compound was not found without adjectival support on the Internet, the item was dropped. Such was the case in (20).

(20) The important thing is that we are going to create a major new international brands business in Britain – the first since Beecham’s in the 1950s.

Because brands business appears to be non-existent, the connection between international and brands was considered too close to warrant the inclusion of this item in the database.

The data collection procedure generated strings of adjectives without making any prior assumptions about the relationship among them or between the adjectives and the nouns. These relationships will be examined in the next section. The above criteria helped to ensure a certain independence of the adjectives from one another and the theoretical possibility of a given adjective to modify either of the nominal constituents.

Two native speakers independently worked out the modification patterns. They were given no specific instructions beyond the task of determining which reading made most sense to them given the context in which the critical NPs were embedded. They were given as much context as they needed to be certain of their judgement. Thus, the decisions were entirely based on semantic rather than formal criteria. Note that these complex NPs often allow for more than a single analysis. Therefore, the native speakers were asked to provide what they considered the most likely interpretation. As a result, the ensuing data analysis is based on preferred interpretations, not on exclusively unambiguous interpretations. To illustrate, let us borrow the example severe cancer pain from the next section. While the adjective severe combines naturally with both cancer and pain, the native-speaker consultants clearly favoured the association of severe with pain in this particular case.

The few cases in which the two judges dissented and a subsequent discussion was not productive of agreement were left out of consideration. Data cleansing left us with 285 NPs consisting of three adjectives and two-noun compounds.
5. Data analysis

5.1 An analysis of triple-adjective NPs

Let us begin the empirical analysis with the discussion of a few relevant examples from the BNC.

(21) Overwhelming pain is a term used to emphasize a common result of chronic unrelieved severe cancer pain.

(22) France and West Germany had presented a proposal for an immediate coordinated financial aid package amounting to some $15,000 million.

(23) In certain areas law centres, staffed by professional lawyers and advisers, offer a good free legal advice service.

(24) The object of this research is to compile statistics in US dollars terms of annual Soviet economic aid deliveries.

Case (21) exemplifies convergent head modification. All three adjectives modify the head pain rather than the cause of the pain. Convergent modifier modification is illustrated in (22) where the three adjectives describe the kind of aid that is offered. Divergent modification is attested in (23) and (24). The former example can be paraphrased as a service which is both good and free and which pertains to legal advice. The latter example is about annual deliveries of Soviet economic aid.

Before we move on to the results, a structural analysis of the above NPs will be proffered. As in diagrams (1) and (2), dependency information will be woven into the constituent structure. This is appropriate given the fact that the adjective-noun relationship is a prototypical instance of a modifier-head relationship.

(25) Convergent head modification

```
NP
 _modifier
   Modifier
      A A A
  head
    N N
      cancer pain
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(26) Convergent modifier modification

NP
   Modifier  Head
     Modifier  Head
         A     A
     immediate  coordinated
     financial

(27) Divergent head modification

NP
   Modifier  Head
     Modifier  Head
         A     A
     good       free
     legal      advice
     service

(28) Divergent modifier modification

NP
   Modifier  Head
     Modifier  Head
         A     A
     annual    Soviet
     economic  aid
     deliveries

The diagrams in (25)–(28) are minimalist in the sense that they postulate only as much structure as is necessary to represent the decisions of the native speakers in formal terms. In particular, the adjectives that modify the same nominal constituent are dominated by the same superordinate node. This leads to binary branching in divergent modification but ternary branching in convergent modification. The implication here would be that these adjectives have exactly the same
status vis-à-vis the nouns. This may not be entirely true, as it could be argued, for example, that *financial* and *aid* form a tighter bond than *immediate* and *aid* in (26). Nonetheless, the structures given in (25)–(28) are sufficient to describe the modification patterns under investigation.

Table 1 presents the frequency of the modification types defined in (9)–(16) above.

<table>
<thead>
<tr>
<th>Modification Type</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergent head modification</td>
<td>110</td>
<td>38.6</td>
</tr>
<tr>
<td>Convergent modifier modification</td>
<td>10</td>
<td>3.5</td>
</tr>
<tr>
<td>Divergent head modification</td>
<td>113</td>
<td>39.6</td>
</tr>
<tr>
<td>Divergent modifier modification</td>
<td>52</td>
<td>18.2</td>
</tr>
<tr>
<td>Crossed modification</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>285</strong></td>
<td><strong>99.9</strong></td>
</tr>
</tbody>
</table>

As can be seen from Table 1, the various modification types display different frequency profiles. Divergent head modification stands out as the most frequent modification type, even though convergent head modification is only minimally less frequent. Divergent modifier modification comes third, with less than half the frequency of the head modification types. Convergent modifier modification is a highly infrequent option. Not a single instance of crossed modification emerges from the data.

Head modification is clearly more common than modifier modification. The former type accounts for almost 4 out of 5 cases. Both convergent and divergent modification are strongly represented in the data, with divergent modification being favoured over convergent modification (57.9% vs. 42.1%; binomial, \( p < 0.001 \)).

There is a remarkable connection between the rate of nominal-head modification and the number of modifying adjectives. Broadly speaking, the higher the number of adjectives, the higher the frequency of head modification. The option of no adjective modifying the head occurs in only 3.5%, single-adjective modification in 18.2%, double-adjective modification in 39.6% and triple-adjective modification in 38.6% of all cases. With the exception of the final two types, which are of roughly equal frequency, we observe a steady increase in modification rate with an increasing number of adjectives modifying the head of the compound.

It is noteworthy that the first adjective is especially prone to modify the head of the compound. Only 3.5% of cases do not follow this rule. More generally, there is an intriguing relationship between adjective position and probability of head
modification. The closer the adjective stands to the nominal compound, the lower the likelihood of head modification (first adjective: 96.5%, second adjective: 78.2%, third adjective: 38.6%).

The preceding analysis rests on the assumption that the various modification types are all equiprobable. This is a perfectly reasonable hypothesis within an atemporal approach in which the complex NP is viewed holistically, i.e. where all parts of the NP are simultaneously available. However, this is not the only possible approach. An alternative view is what may be called the linear model in which the constituents of the NP are scanned from left to right. That is, the decision on the modification target of the first adjective serves as input to the decision on the modification target of the second adjective (and likewise for the third adjective). In other terms, earlier decisions constrain later decisions. Such an approach renders it necessary to calculate conditional probabilities. Hence, it is incompatible with the assumption of equiprobability.

The major constraining factor in the modification decisions is the absence of crossed modification in the data. If this absence is interpreted as a ban on crossed modification, this ban limits the number of available choices. For the sake of clarity, the effects of line crossing are explicated in the following four conditions providing the probability of the different modification types. These types are given in brackets after the conditions. As in diagrams (1) and (2), the arrow stands for “modifies”. The approach adopted here is purely formal, i.e. it ignores possible biases which speakers may have internalized as a result of their experience with the language.

(29) If $A_1 \rightarrow N_1$, then $A_2$ and $A_3$ have a probability of 1 of targeting $N_1$ (convergent modifier modification).

(30) a. If $A_1$ and $A_2 \rightarrow N_2$, then $A_3$ has a probability of 0.5 of targeting $N_2$ (convergent head modification).
   b. If $A_1$ and $A_2 \rightarrow N_2$, then $A_3$ has a probability of 0.5 of targeting $N_1$ (divergent head modification).

(31) If $A_1 \rightarrow N_2$ and $A_2 \rightarrow N_1$, the $A_3$ has a probability of 1 of targeting $N_1$ (divergent modifier modification).

The probabilities for the various modification types are summarized in (32).

(32) a. convergent head modification: 0.5
b. convergent modifier modification: 1.0
c. divergent head modification: 0.5
d. divergent modifier modification: 1.0
According to this method, the baseline probability of modifier modification is twice as high as that of head modification. To provide for an equal opportunity of occurrence, the rate of the two subtypes of modifier modification has accordingly to be halved. Since this amendment affects the two less common categories, the contrast between modifier and head modification is greatly enhanced. However, the frequency ranks of the four modification types remain unaltered. Thus, the linear model yields empirical results which are similar to those of the atemporal model. It would therefore seem unnecessary to distinguish between the two approaches.

Summarizing, the different modification types display the following pattern of results. There are two fairly common types of roughly equal frequency (convergent and divergent head modification), one moderately frequent type (divergent modifier modification), one infrequent type (convergent modifier modification) and one unattested type (crossed modification). In the next subsection, these findings will be compared to those obtained for NPs with two attributive adjectives.

5.2 Comparison with double-adjective NPs

In some respects, it is possible to compare double-adjective and triple-adjective + double-noun NPs. Let us begin with a look at convergent head vs. convergent modifier modification, the two categories which are immediately comparable despite the differing number of adjectives involved. The double-adjective study was based on 327 convergent modifications of which 298 implicated the head and 29 the modifier of the compound. This proportion is virtually identical to that of the present work ($\chi^2(1)= 0.0$, n.s.). Hence, the distinction between heads and modifiers in convergent modification plays the same role in double- and triple-adjective NPs.

Another commonality lies in the complete absence of crossed modification in both double- and triple-adjective + nominal compound sequences. The assumed ban on line crossing thus appears to be of a general nature.

Unfortunately, the two types of NP under discussion do not lend themselves readily to a comparison of convergent vs. divergent modification. This is because there are two possibilities of divergent modification in triple-adjective NPs but only one in double-adjective NPs. What is more, the definitions of divergence are not the same in the two types of NP. Whereas divergent modification is a pure category in double-adjective NPs, divergent modification actually represents a mixed category in triple-adjective NPs because two adjectives converge on one nominal constituent and thereby diverge from the third adjective. This makes it difficult, if not impossible, to compare the rate of divergent modification in triple- and double-adjective NPs.
The double-adjective study found the distinction between heads and modifiers to be a more important determinant of the empirical patterns than the distinction between convergent and divergent modification. This result could be replicated in the present investigation even though the strength of these two factors differed more strongly in the triple-adjective than in the double-adjective analysis.

In brief summary, the double-adjective NPs and the triple-adjective NPs are subject to similar constraints. Obviously, this conclusion applies only to those points on which the two datasets are directly comparable.

6. Theoretical discussion

The preceding analysis has produced a set of results which can be explained by a small number of principles, all of which have been established on independent grounds. To be specific, the principles of functional status and proximity and the no-crossing constraint suffice to explain the empirical data. These will be discussed in the following.

6.1 Function and proximity

Functional status rests on the asymmetry between heads and modifiers. As customarily understood, the heads of compounds determine the properties of the entire compound and thus indirectly make contact with other elements in the same utterance. There is ample evidence for the differential importance of heads and modifiers. For example, Libben et al. (2003) showed that the semantic transparency of the head, though not that of the modifier, determined the processing difficulty of compounds. Significantly, several studies (e.g. Gagné 2001; Marelli et al. 2009; Zwitserlood 1994) observed a larger priming effect caused by heads than by modifiers. This helps us to understand why heads are more “visible”, and hence more suitable modification targets, than modifiers. It is this higher “visibility” which accounts for the predominance of head modification over modifier modification.

Functional status nicely explains the differential frequency of divergent head modification (highly frequent), divergent modifier modification (moderately frequent) and convergent modifier modification (infrequent). This pattern is a function of the number of adjectives going on the head and thereby satisfying the

4. The structural factor played no role in the present analysis because it comes into play in more complex nominal compounds than were investigated here. Bipartite compounds allow for no variation in terms of internal structure.
functional principle. Convergent modifier modification has no adjective, divergent modifier modification has one adjective and divergent head modification has two adjectives modifying the head.

While functional status can explain the preponderance of head modification as such, it cannot explain the equal rate of convergent and divergent head modification in the data. Since all three adjectives modify the head in convergent modification but only two in divergent modification, functional status would lead us to expect a higher rate of the former than of the latter type. Therefore, there must be another factor which facilitates the occurrence of divergent head modification. This factor raises this modification type above the level of convergent head modification (if only slightly so).

The high rate of divergent head modification is claimed here to be brought about by proximity. There is plenty of empirical evidence to bolster this principle, both in linguistics and psycholinguistics (e.g. Belnap 1999; Curzan 2003; Gibson 1998; Henson et al. 1996; Larson 1991; Nakayama & Saito 2014). The main effect of this principle is to increase the interaction rate of adjacent elements. It elevates the probability of the rightmost adjective modifying the leftmost noun. In conjunction with functional status, proximity occasions divergent head modification. The unexpectedly high frequency of this modification type can now be seen as the joint product of functional status and proximity, with the former factor being responsible for the association of the first two adjectives with the head and the latter factor being responsible for the association of the third adjective with the nominal modifier of the compound.

Proximity may be at least partly responsible for bringing about the curious interaction of adjective position and head modification: the further away an adjective is from the nominal compound, the higher the likelihood of its modifying the head. Since proximity is a linear principle, it is only natural to invoke it to capture this linear effect. Proximity certainly leads us to expect the low modification rate of the nominal head by the third adjective because it facilitates the association of this very adjective with the nominal modifier. Let us assume that the range of the proximity principle does not drop off completely at the boundary separating the second and the third adjective. It may then be argued that the effect of proximity lessens with increasing distance. Therefore, proximity impacts less on the first than on the second adjective. As a result, the first adjective is more likely to go on the nominal head than is the second, which in turn is more likely to modify the head than is the third.

The proximity principle is generally relevant in all modification types involving the modification of the nominal modifier by the final adjective. That is, it should play a role not only in divergent head modification but also in convergent and divergent modifier modification. In point of fact, the empirical data do not
contradict this claim. All that has to be assumed is that the rates of these three modification types would be lower if the proximity principle was not in place.

This reasoning brings us near an explanation of the predominance of divergent over convergent modification. The proximity principle increases the likelihood of occurrence of both types of divergent modification but only one type of convergent modification, which is anyway extremely unlikely.

By way of internal conclusion, functional status and proximity are claimed to be antagonistic forces. Whereas the former favours convergent head modification, the latter favours the other three modification types. The fact that the rate of these other types is heavily dependent on the extent of head modification (see above) strongly suggests that functional status is a more powerful effect than proximity.

It is important to understand that functional status and proximity simultaneously influence the modification patterns (albeit in different ways). To make this possible, it is necessary to link up the two factors and find a common currency for them. This common currency is the notion of accessibility, which plays a major role in linguistic and even more so in psycholinguistic theorizing (e.g. Ariel 1988; Bock 1987; Christianson & Ferreira 2005; Keenan & Comrie 1977; Prat-Sala & Branigan 2000; Ward et al. 1991). Our starting point is that, in order to be used, lexical items have to be retrieved from the mental lexicon. The access procedure necessary for retrieval may be more or less difficult. Therefore, some units are more (readily) available than others at a given moment in time. The accessibility of lexical items depends on a number of factors which may be broadly divided into linear and hierarchical ones. The linear factor refers to syntagmatic relationships among linguistic units. The closer the elements are to the unit that is currently being outputted, the higher the availability of these neighbours. This is the psycholinguistic underpinning of the proximity principle. The hierarchical factor is grounded in the assumption that elements which are more salient in the structural hierarchy are easier to access. Because heads are by definition more salient, they are easier to retrieve than modifiers.

The general claim is, then, that the modification patterns are determined by the differential accessibility of the modification targets. The nouns that are more often singled out for modification are precisely those which are more accessible (for reasons which are largely, if not fully, independent of the task of associating a particular adjective with a particular noun). The notion of accessibility will be placed in a wider communicative context in Section 6.3.

6.2 The no-crossing constraint

We now turn to the third principle – the no-crossing constraint. The fact that crossed modification is completely missing from the corpus deserves particular
attention. We might content ourselves with attributing this finding to the no-crossing constraint and leave it at that. However, what keeps us from stopping at this point is that the no-crossing constraint formalizes an empirical observation but it does not by itself have any explanatory power. It rather pinpoints the explanandum. In this spirit, an attempt will be made to provide a functional explanation for an empirical phenomenon which is putatively captured by the no-crossing constraint (see also Berg 2014).

To understand why association lines do not cross, it is helpful to return to the distinction between syntactic and morphological modification referred to in the beginning section. Rephrasing the empirical analysis in terms of this distinction, we observe that morphological modification always occurs with adjectives that are closer to the nominal compound than those adjectives involved in syntactic modification. In other words, morphological modification never precedes syntactic modification in the linear utterance. In fact, there is very good reason for syntactic modification to be further away from the head of the compound than morphological modification. It is a truism that morphological and syntactic units differ in scope. Morphological complexes are confined by word boundaries whereas syntactic complexes involve units larger than the word. So when a complex word (viewed as an independent unit) is built up, morphological building blocks are assembled. No other building blocks (such as syntactic ones) are eligible because these would destroy the lexical status of the word and ultimately lead to the abolishment of language as a multi-level system. The hierarchical organization of language thus prevents syntactic material from occurring inside words (to a greater or lesser extent, see below). If syntactic modification was positioned closer to the noun than morphological modification, the word would inevitably incorporate syntactic material in a morphological structure. The undesirability of this confusion of levels is at the bottom of the absence of crossed modification.

This structural analysis may be supplemented by adopting a communicative perspective. In the process of understanding utterances, listeners have to work out the functions of linguistic units and their interrelationships. In particular, they have to determine which adjective modifies which nominal constituent. This task presupposes the existence of cues which listeners can rely on. Cues typically used by languages to this end include inflectional marking and word order. Inflectional marking is out of the question because adjectives in their positive form are invariant in English. Hence, English has to resort to word order. Crucially, word order can only be a reliable cue if it is fixed. The possibility of alternative orders (i.e. syntactic modification before morphological modification and vice versa) would render ordering information useless because listeners would have no way of correctly associating the different adjectival modifiers with their nominal heads.
However appealing the above analysis may be, the claim that syntactic material is banned from the within-word domain is not entirely correct. English is perfectly capable of accommodating syntactic material within compounds, thereby undermining the pervasive structural principle of larger units being made up of smaller ones. These cases, commonly dubbed phrasal compounds, have been amply documented in the pertinent literature (see e.g. Lieber 1992, from which the following examples are borrowed).

(33)  a. a pipe and slipper husband
     b. a connect the dots puzzle
     c. a who’s the boss wink

Different types of syntactic material act as modifiers in these compounds: an NP in (33a), a VP in (33b) and a full sentence in (33c). These examples leave little doubt that English tolerates the confusion of levels banished above. The real question thus is under which circumstances the infiltration of morphology by syntax is allowed or disallowed. What, then, distinguishes phrasal compounds from crossed modification? We may begin to appreciate this difference by focusing again on the listener’s perspective. To successfully decode an utterance, the listener must rely on perceptual clues. Two important aspects of this decoding process are the correct identification of word classes and the establishment of structural relations among the linguistic units. In phrasal compounds, the listener takes the determiner as a perceptual clue, which signals the beginning of an NP. If the following word is not an adjective, the listener has good reason to hypothesize that a (simple or complex) noun is coming up. This heuristic provides a frame within which the incoming material can be accommodated.

Crucially, successful processing can not only be effected for ordinary (i.e. non-phrasal) but also for phrasal compounds because the identification of both types of compounds relies on the same strategy of assigning modifier status to the following lexeme. If this lexeme is a noun followed by another noun, the compound is identified as non-phrasal. If, however, this lexeme is either a non-noun (33b) or a noun followed by a non-noun (33a), the compound is assigned phrasal status. In a nutshell, phrasal compounds are not impenetrable even though they involve a mixture of syntactic and morphological information.

The crossed modification of nominal compounds by adjectives is different. There is no formal clue (like the determiner in phrasal compounds) to signal a particular relationship between an adjective and a nominal constituent. As noted before, the formal invariance of adjectives precludes the morphological marking of specific relations. In an effort to compensate for the lack of inflectional marking, listeners resort to word order. The two theoretically possible orders, viz. syntactic modification preceding morphological modification and vice versa, display a
critical difference. Syntactic before morphological modification is the more iconic of the two orders. According to Behaghel’s First Law (Behaghel 1932: 4), the temporal or spatial proximity of meaningful elements in an utterance mirrors their conceptual closeness. Morphological information is more intimately tied to the compound than syntactic information because the former aims at the ‘inside’ whereas the latter aims at the ‘outside’ of the compound. Morphological information must therefore be closer to the compound than syntactic information. This automatically gives rise to the attested order and at the same time bans the unattested one.

This explanation presents the no-crossing constraint in a new light. However adequate this principle may be descriptively, it 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. The true reason for the non-occurrence of crossed modification lies in the impossibility of erecting the correct structural representation for crossed modification patterns given the well-formedness of nested modification (i.e. $A_1 \rightarrow N_3$ and $A_2 \rightarrow N_1$). If both nested and crossed modification were licit, there would be no way of distinguishing between these two modification types because English provides no relevant formal clues. Therefore, the two cannot co-exist and one has to outcompete the other. Owing to its higher iconicity, nested modification trumps crossed modification. This explains the complete absence of crossed modification in the corpora on which the present study and the second part of this trilogy are based.

6.3 The communicative perspective

Finally, it is instructive to place the modification patterns in a broader perspective and examine whether they are speaker- or listener-based phenomena. At first sight, the answer appears to be self-evident. A viable explanation of the modification patterns presupposes knowledge of the nature of the complex NP. This knowledge is available to the speaker, whose advance planning arguably extends to the phrase level, though not to the listener, who cannot know in advance that a complex NP with several adjectives and a nominal compound is about to be produced. Before we can accept this conclusion, it is necessary to consider the listener’s perspective in more detail.

Through their previous exposure to language, listeners have learnt to build up expectations about what is to be expected in an utterance. These expectations are continuously updated in the on-line comprehension process. Crucially, these expectations are frequency-based. That is, when unit X has a high probability of being followed by unit Y, listeners will expect Y upon hearing X.

It has been demonstrated that simplex nouns are more frequent than compound nouns in English (Berg et al. 2012). Moreover, single-adjective NPs are
more common than double-adjective NPs which in turn are more common than triple-adjective NPs. These frequency biases have important repercussions for listeners and the strategies they develop. Due to the complexity and hence infrequency of the linguistic patterns under investigation, listeners will expect neither a compound noun nor a second or even a third adjective when they encounter the first adjective of an NP. Thus, on principled grounds, the listener’s perspective cannot explain the empirical data, or so it would seem.

This argument rests on the validity of what we may call the identity assumption. This assumption holds that the same constituents in less complex or more complex units are phonetically identical. If true, hearing the initial constituent would provide listeners with no clue as to the size of the phrase; however, if not, the above argument would founder. As a matter of fact, evidence against the identity assumption has been accumulating in recent years. Several studies have shown that a free-standing word and the “same” unit as part of a polysyllabic word or as part of a compound are phonetically distinct and moreover, that listeners are sensitive enough to pick up these differences (e.g. Davis et al. 2002; Isel et al. 2003; Koester et al. 2004). While it is not known whether these results also hold across word boundaries, they raise the possibility that similar phonetic effects might emerge at the phrase level. If this possibility is real, listeners would be able to make informed guesses about the size of the NP on the basis of the first word that they process.

Thus, it seems wise not to prematurely dismiss the role of the listener in bringing about the modification patterns. Rather than pitting listeners against speakers, we prefer an explanation which accommodates both. This account acknowledges that the modification patterns originate with speakers but makes the additional claim that they are shaped by perceptual constraints. More specifically, speakers select modification types as a function of the assumed processing cost that the various NPs incur for listeners. Structures which are easy to decode are produced more frequently than structures which impose a heavy decoding load. In this way, speakers alleviate the listeners’ task of ferreting out the relationships within complex NPs. Let us illustrate this principle on the basis of the strong association of the initial adjective with the head of the compound. Underlying this strong association is a frequency effect. As noted above, the most frequent type of NP has a single adjective (if it has an adjective at all). This adjective most usually modifies the head of the following compound (Berg 2011). On hearing the (first) adjective, listeners build up the expectation that this is the only adjective and that it modifies the nominal head, irrespective of whether the head is a single noun or part of a compound. Being listeners themselves, speakers know that listeners employ such a heuristic. So even when speakers flout listeners’ expectations of a single adjective coming up by uttering a second (and third) adjective, they make sure that not all of the listeners’ expectations are violated. In particular, they have the first
adjective modify the nominal head because this is what listeners strongly expect them to do. If the first adjective does not modify the head, listeners will be led down the garden path and discover that their initial structural analysis is wrong (e.g. MacDonald et al. 1994; Pickering & Traxler 1998; Slattery et al. 2013). They will then have to revise their initial hypothesis. Since this is a costly process (see Gibson 1998), it is only natural to assume that speakers make an effort to avoid leading listeners astray. Specifically, they do so by associating the initial adjective with the head of the compound in the vast majority of cases.

The pull of the second adjective towards the head in triple-adjective + two-noun compounds is still quite strong but considerably weaker than that of the first. This effect is also due to language users’ sensitivity to frequency distributions. As double-adjective NPs are more frequent than triple-adjective NPs and as double-adjective NPs exhibit a relatively high rate of nested modification (with the second adjective going on the nominal modifier of the compound), listeners build up a lower expectation that the second adjective will modify the head. So speakers have greater freedom in making the second adjective modify a non-head. The relatively weak association of the third adjective with the head of the compound can be explained along similar lines.

To conclude, English presents an intriguing case of a language lacking reliable formal criteria for working out the modification relationships between multiple adjectives and nouns in complex NPs. Neither serial order nor position can be blindly relied on. While these two factors provide some probabilistic clues, they cannot replace semantic criteria. Occasionally, listeners cannot even form frequency-based expectations. Take the example of convergent and divergent head modification. The only difference between the two types is whether the third adjective goes on the head or the modifier of the compound. As both modification types are equally common, there is no way of predicting whether the one or the other modification was chosen by the speaker. Hence, listeners have to work out the correct modification type in each NP which they come across. The modification patterns provide yet another example of the indeterminacy which Hawkins (1986) argued to be so characteristic of English.

7. Ever more complex cases

Before concluding, let us briefly look beyond triple-adjective + bipartite-noun NPs. We may increase their size on two fronts by enlarging the number of adjectives or the complexity of the nominal compound. Not surprisingly, such juggernauts occur even less often than the NPs under consideration in this paper. In fact, the BNC produces a few such cases, among which are (34)–(36).
(34) Taking advantage of the above is the new Asian International Contemporary Art Fair which …

(35) To summarize, for a well flagged group of patients, with small solitary non-invasive transition cell carcinomas at diagnosis and negative three month cytoscopy, …

(36) … we made the most of the fact that a poor struggling little community service radio station … was being victimized by a powerful political federal body …

Example (34) has a total of four adjectives modifying a bipartite compound. In (35) and (36), the number of prenominal adjectives is kept at three but compound size is increased. The three adjectives modify a tripartite left-branching compound in (35) but a four-noun symmetrical (2 + 2) compound in (36). As noted before, these three modification types are so uncommon that they defy a statistical analysis. The BNC search unearthed 10 four-adjective + two-noun NPs, 3 three-adjective + three-noun NPs and 3 three-adjective + four-noun NPs. An examination of these cases reveals some commonalities with the previously investigated NPs. In particular, not a single instance of line crossing was uncovered. Furthermore, the three adjectives exhibit sensitivity to the internal structure of three- and four-noun compounds. The upshot of these observations is that the more complex cases in (34)–(36) seem to be subject to the same principles that were shown to govern the linguistic patterns dealt with in this study and its prequels.

8. Conclusion

At the end of this trilogy, it is fitting to take stock. English allows not only multiple attribution (as presumably most languages do) but also recursive compounds. These compounds may accommodate not only nominal but also adjectival modifiers. This structural freedom generates a relatively large number of options for modification in complex NPs. This range of options was explored in the present trilogy. The modification patterns were found to be highly constrained, both qualitatively and quantitatively. The major constraint shaping the empirical data is that the modification types intended by speakers and writers must be recoverable for listeners and readers. This principle rules out crossed modification. The modification patterns that are actually attested are under the sway of factors which operate in general language usage and thus do not have to be specifically postulated for the modification of nouns by adjectives. The distinction between heads and modifiers is a time-honoured principle which applies to a wide variety of relationships beyond that between nouns and adjectives. In addition, it applies not only to the
syntactic, but also to the morphological and (in some frameworks) to the phono-
logical level. The same is true of structural representations which are operative at
all levels of linguistic analysis. The depth of a structural representation has many
ramifications beyond the ones discussed in this trilogy. For instance, word order
freedom is known to correlate with structural depth. In keeping with Ross’s (1973)
Penthouse Principle, which allows a larger number of structural options in hierar-
chically higher branches of the syntactic tree, this freedom decreases with increas-
ing structural depth. The proximity principle is also applicable at different analyti-
cal levels. It manifests itself in all kinds of phenomena ranging from phonotactic
effects in phonology (phonotactic constraints are stronger between adjacent than
between non-adjacent phonemes) to agreement effects in syntax (in agreement
conflicts, controllers adjacent to the target make a stronger impact than control-
lers further away from the target). The bottom line of the preceding discussion is
that the principles claimed to underlie the modification patterns under study have
a firmly established place in linguistic analysis. No extra theoretical machinery is
needed to account for the modification of nouns by adjectives.

These principles can be bound together by invoking the notion of accessibility.
The general idea is that the likelihood of target selection is a function of the avail-
ability of the nominal constituent. The higher its availability, the higher the likeli-
hood of its selection. A noun’s availability is increased by each of the factors referred
to in the foregoing. Almost by definition, heads are more available than modifiers.
Less deeply embedded nominal constituents are more available than more deeply
embedded ones because more deeply embedded units are more tightly integrated
into a larger structure, which can be broken up less easily. Adjacent elements have a
higher degree of co-activation than non-adjacent ones. The immediately following
element is more available than elements further ahead because it is needed earlier
in the production process. All these effects add up in the sense that they jointly
determine the availability of a noun. Hence, the higher the availability of a nominal
constituent, the more frequently it will be chosen as a target for modification.

Acknowledgements

As in the previous parts of this project, I have the pleasure to express my heartfelt thanks to a
team of experts who have variously contributed to the materialization of this paper. Marion
Neubauer not only encouraged me to look at triple-adjective NPs, but also pulled the data out
of the BNC. Melissa Neitzel and Nigel Isle mused over the modification patterns with me. I am
also grateful to the editor, Martin Hilpert, and an anonymous reviewer for their dedication and
detailed comments.
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Author’s address

Thomas Berg
Department of English
University of Hamburg
Von-Melle-Park 6
20146 Hamburg
Germany

thomas_berg@uni-hamburg.de