2 Phrase structure grammar

This chapter deals with phase structure grammars, which play an important role in several of the theories we will encounter in later chapters.

2.1 Symbols and rewrite rules

Words can be assigned to a particular part of speech on the basis of their inflectional properties and syntactic distribution. Thus, *weil* 'because' in (1) is a conjunction, whereas *das* 'the' and *dem* 'the' are articles and therefore classed as determiners. Furthermore, *Buch* 'book' and *Mann* 'man' are nouns and *gibt* 'gives' is a verb.

(1) weil er das Buch dem Mann gibt
because he the book the man gives
'because he gives the man the book'

Using the constituency tests we introduced in Section 1.3, we can show that individual words as well as the strings *das Buch* 'the book' and *dem Mann* 'the man', form constituents. These get then assigned certain symbols. Since nouns form an important part of the phrases *das Buch* and *dem Mann*, these are referred to as *noun phrases* or NPs, for short. The pronoun *er* 'he' can occur in the same positions as full NPs and can therefore also be assigned to the category NP.

Phrase structure grammars come with rules specifying which symbols are assigned to certain kinds of words and how these are combined to create more complex units. A simple phrase structure grammar which can be used to analyze (1) is given in (2):[1,2]

(2)

NP → D N	NP → er	N → Buch
S → NP NP NP V	D → das	N → Mann
	D → dem	V → gibt

We can therefore interpret a rule such as NP → D N as meaning that a noun phrase, that is, something which is assigned the symbol NP, can consist of a determiner (D) and a noun (N).

[1] I ignore the conjunction *weil* 'because' for now. Since the exact analysis of German verb-first and verb-second clauses requires a number of additional assumptions, we will restrict ourselves to verb-final clauses in this chapter.

[2] The rule NP → er may seem odd. We could assume the rule PersPron → er instead but then would have to posit a further rule which would specify that personal pronouns can replace full NPs: NP → PersPron. The rule in (2) combines the two aforementioned rules and states that *er* 'he' can occur in positions where noun phrases can.

We can analyze the sentence in (1) using the grammar in (2) in the following way: first, we take the first word in the sentence and check if there is a rule in which this word occurs on the right-hand side of the rule. If this is the case, then we replace the word with the symbol on the left-hand side of the rule. This happens in lines 2–4, 6–7 and 9 of the derivation in (3). For instance, in line 2 *er* is replaced by NP. If there are two or more symbols which occur together on the right-hand side of a rule, then all these words are replaced with the symbol on the left. This happens in lines 5, 8 and 10. For instance, in line 5 and 8, D and N are rewritten as NP.

(3)

	words and symbols						rules that are applied
1	er	das	Buch	dem	Mann	gibt	
2	NP	das	Buch	dem	Mann	gibt	NP → er
3	NP	D	Buch	dem	Mann	gibt	D → das
4	NP	D	N	dem	Mann	gibt	N → Buch
5	NP		NP	dem	Mann	gibt	NP → D N
6	NP		NP	D	Mann	gibt	D → dem
7	NP		NP	D	N	gibt	N → Mann
8	NP		NP		NP	gibt	NP → D N
9	NP		NP		NP	V	V → gibt
10						S	S → NP NP NP V

In (3), we began with a string of words and it was shown that we can derive the structure of a sentence by applying the rules of a given phrase structure grammar. We could have applied the same steps in reverse order: starting with the sentence symbol S, we would have applied the steps 9–1 and arrived at the string of words. Selecting different rules from the grammar for rewriting symbols, we could use the grammar in (2) to get from S to the string *er dem Mann das Buch gibt* 'he the man the book gives'. We can say that this grammar licenses (or generates) a set of sentences.

The derivation in (3) can also be represented as a tree. This is shown by Figure 2.1. The

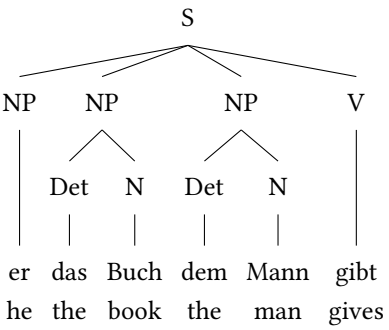

Figure 2.1: Analysis of *er das Buch dem Mann gibt* 'he the book the woman gives'

symbols in the tree are called *nodes*. We say that S immediately dominates the NP nodes

and the V node. The other nodes in the tree are also dominated, but not immediately dominated, by S. If we want to talk about the relationship between nodes, it is common to use kinship terms. In Figure 2.1, S is the mother node of the three NP nodes and the V node. The NP node and V are sisters since they have the same mother node. If a node has two daughters, then we have a binary branching structure. If there is exactly one daughter, then we have a unary branching structure. Two constituents are said to be *adjacent* if they are directly next to each other.

Phrase structure rules are often omitted in linguistic publications. Instead, authors opt for tree diagrams or the compact equivalent bracket notation such as (4).

(4) [$_S$ [$_{NP}$ er] [$_{NP}$ [$_D$ das] [$_N$ Buch]] [$_{NP}$ [$_D$ dem] [$_N$ Mann]] [$_V$ gibt]]
he the book the man gives

Nevertheless, it is the grammatical rules which are actually important since these represent grammatical knowledge which is independent of specific structures. In this way, we can use the grammar in (2) to parse or generate the sentence in (5), which differs from (1) in the order of objects:

(5) [weil] er dem Mann das Buch gibt
because he.NOM the.DAT man the.ACC book gives
'because he gives the man the book'

The rules for replacing determiners and nouns are simply applied in a different order than in (1). Rather than replacing the first Det with *das* 'the' and the first noun with *Buch* 'book', the first Det is replaced with *dem* 'the' and the first noun with *Mann*.

At this juncture, I should point out that the grammar in (2) is not the only possible grammar for the example sentence in (1). There is an infinite number of possible grammars which could be used to analyze these kinds of sentences (see exercise 1). Another possible grammar is given in (6):

(6)
NP → D N	NP → er	N → Buch
V → NP V	D → das	N → Mann
	D → dem	V → gibt

This grammar licenses binary branching structures as shown in Figure 2.2 on the following page.

Both the grammar in (6) and (2) are too imprecise. If we adopt additional lexical entries for *ich* 'I' and *den* 'the' (accusative) in our grammar, then we would incorrectly license the ungrammatical sentences in (7b–d):[3]

[3] With the grammar in (6), we also have the additional problem that we cannot determine when an utterance is complete since the symbol V is used for all combinations of V and NP. Therefore, we can also analyze the sentence in (i) with this grammar:

(i) a. * der Mann erwartet
the man expects

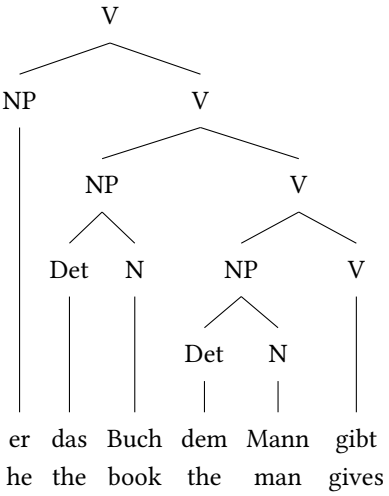

Figure 2.2: Analysis of *er das Buch dem Mann gibt* with a binary branching structure

(7) a. er das Buch dem Mann gibt
he.NOM the.ACC book the.DAT man gives
'He gives the book to the man.'

b. * ich das Buch dem Mann gibt
I.NOM the.ACC book the.DAT man gives

c. * er das Buch den Mann gibt
he.NOM the.ACC book the.ACC man gives

d. * er den Buch dem Mann gibt
he.NOM the.M book(N) the man gives

In (7b), subject-verb agreement has been violated, in other words: *ich* 'I' and *gibt* 'gives' do not fit together. (7c) is ungrammatical because the case requirements of the verb have not been satisfied: *gibt* 'gives' requires a dative object. Finally, (7d) is ungrammatical because there is a lack of agreement between the determiner and the noun. It is not possible to combine *den* 'the', which is masculine and bears accusative case, and *Buch* 'book' because *Buch* is neuter gender. For this reason, the gender properties of these two elements are not the same and the elements can therefore not be combined.

In the following, we will consider how we would have to change our grammar to stop

b. * des Mannes er das Buch dem Mann gibt
the.GEN man.GEN he the.DAT book.DAT the man gives

The number of arguments required by a verb must be somehow represented in the grammar. In the following chapters, we will see exactly how the selection of arguments by a verb (valence) can be captured in various grammatical theories.

it from licensing the sentences in (7b–d). If we want to capture subject-verb agreement, then we have to cover the following six cases in German, as the verb has to agree with the subject in both person (1, 2, 3) and number (sg, pl):

(8)
a. Ich schlafe. (1, sg)
I sleep
b. Du schläfst. (2, sg)
you sleep
c. Er schläft. (3, sg)
he sleeps
d. Wir schlafen. (1, pl)
we sleep
e. Ihr schlaft. (2, pl)
you sleep
f. Sie schlafen. (3, pl)
they sleep

It is possible to capture these relations with grammatical rules by increasing the number of symbols we use. Instead of the rule S → NP NP NP V, we can use the following:

(9)
S → NP_1_sg NP NP V_1_sg
S → NP_2_sg NP NP V_2_sg
S → NP_3_sg NP NP V_3_sg
S → NP_1_pl NP NP V_1_pl
S → NP_2_pl NP NP V_2_pl
S → NP_3_pl NP NP V_3_pl

This would mean that we need six different symbols for noun phrases and verbs respectively, as well as six rules rather than one.

In order to account for case assignment by the verb, we can incorporate case information into the symbols in an analogous way. We would then get rules such as the following:

(10)
S → NP_1_sg_nom NP_dat NP_acc V_1_sg_nom_dat_acc
S → NP_2_sg_nom NP_dat NP_acc V_2_sg_nom_dat_acc
S → NP_3_sg_nom NP_dat NP_acc V_3_sg_nom_dat_acc
S → NP_1_pl_nom NP_dat NP_acc V_1_pl_nom_dat_acc
S → NP_2_pl_nom NP_dat NP_acc V_2_pl_nom_dat_acc
S → NP_3_pl_nom NP_dat NP_acc V_3_pl_nom_dat_acc

Since it is necessary to differentiate between noun phrases in four cases, we have a total of six symbols for NPs in the nominative and three symbols for NPs with other cases. Since verbs have to match the NPs, that is, we have to differentiate between verbs which select three arguments and those selecting only one or two (11), we have to increase the number of symbols we assume for verbs.

(11) a. Er schläft.
he sleeps
'He is sleeping.'

b. * Er schläft das Buch.
he sleeps the book

c. Er kennt das Buch.
he knows the book
'He knows the book.'

d. * Er kennt.
he knows

In the rules above, the information about the number of arguments required by a verb is included in the marking 'nom_dat_acc'.

In order to capture the determiner-noun agreement in (12), we have to incorporate information about gender (fem, mas, neu), number (sg, pl), case (nom, gen, dat, acc) and the inflectional classes (strong, weak[4]).

(12) a. der Mann, die Frau, das Buch (gender)
the man the woman the book

b. das Buch, die Bücher (number)
the book the books

c. des Buches, dem Buch (case)
the.GEN book the.DAT book

d. ein Beamter, der Beamte (inflectional class)
a civil.servant the civil.servant

Instead of the rule NP → D N, we will have to use rules such as those in (13):

(13) NP_3_sg_nom → D_fem_sg_nom_weak N_fem_sg_nom_weak
NP_3_sg_nom → D_mas_sg_nom_weak N_mas_sg_nom_weak
NP_3_sg_nom → D_neu_sg_nom_weak N_neu_sg_nom_weak
NP_3_pl_nom → D_fem_pl_nom_weak N_fem_pl_nom_weak
NP_3_pl_nom → D_mas_pl_nom_weak N_mas_pl_nom_weak
NP_3_pl_nom → D_neu_pl_nom_weak N_neu_pl_nom_weak

NP_3_sg_nom → D_fem_sg_nom_stark N_fem_sg_nom_stark
NP_3_sg_nom → D_mas_sg_nom_stark N_mas_sg_nom_stark
NP_3_sg_nom → D_neu_sg_nom_stark N_neu_sg_nom_stark
NP_3_pl_nom → D_fem_pl_nom_stark N_fem_pl_nom_stark
NP_3_pl_nom → D_mas_pl_nom_stark N_mas_pl_nom_stark
NP_3_pl_nom → D_neu_pl_nom_stark N_neu_pl_nom_stark

[4] These are inflectional classes for adjectives which are also relevant for some nouns such as *Beamter* 'civil servant', *Verwandter* 'relative', *Gesandter* 'envoy', ...). For more on adjective classes see page 23.

(13) shows the rules for nominative noun phrases. We would need analogous rules for genitive, dative, and accusative. We would then require 48 symbols for determiners ($3 * 2 * 4 * 2$), 48 symbols for nouns and 48 rules rather than one.

2.2 Expanding PSG with features

Phrase structure grammars which only use atomic symbols are problematic as they cannot capture certain generalizations. We as linguists can recognize that NP_3_sg_nom stands for a noun phrase because it contains the letters NP. However, in formal terms this symbol is just like any other symbol in the grammar and we cannot capture the commonalities of all the symbols used for NPs. Furthermore, unstructured symbols do not capture the fact that the rules in (13) all have something in common. In formal terms, the only thing that the rules have in common is that there is one symbol on the left-hand side of the rule and two on the right.

We can solve this problem by introducing features which are assigned to category symbols and therefore allow for the values of such features to be included in our rules. For example, we can assume the features person, number and case for the category symbol NP. For determiners and nouns, we would adopt an additional feature for gender and one for inflectional class.

(14) NP(3,sg,nom) → D(fem,sg,nom,strong) N(fem,sg,nom,strong)
NP(3,sg,nom) → D(mas,sg,nom,strong) N(mas,sg,nom,strong)

If we were to use variables rather than the values in (14), we would get the following rules as in (15):

(15) NP(3,Num,Case) → D(Gen,Num,Case,Infl) N(Gen,Num,Case,Infl)

The values of the variables here are not important. What is important is that they match. The value of the person feature (the first position in the NP(3,Num,Case)) is fixed at '3' by the rule. These kind of restrictions on the values can, of course, be determined in the lexicon:

(16) NP(3,sg,nom) → es
D(mas,sg,nom,strong) → des

The rules in (10) can be collapsed into a single schema as in (17):

(17) S → NP(Per1,Num1,nom)
NP(Per2,Num2,dat)
NP(Per3,Num3,acc)
V(Per1,Num1,ditransitive)

The identification of Per1 and Num1 on the verb and on the subject ensures that there is subject-verb agreement. For the other NPs, the values of these features are irrelevant. The case of these NPs is explicitly determined.

2.3 Semantics

In the introductory chapter and the previous sections, we have been dealing with syntactic aspects of language and the focus will remain very much on syntax for the remainder of this book. It is, however, important to remember that we use language to communicate, that is, to transfer information about certain situations, topics or opinions. If we want to accurately explain our capacity for language, then we also have to explain the meanings that our utterances have. To this end, it is necessary to understand their syntactic structure, but this alone is not enough. Furthermore, theories of language acquisition that only concern themselves with the acquisition of syntactic constructions are also inadequate. The syntax-semantics interface is therefore important and every grammatical theory has to say something about how syntax and semantics interact. In the following, I will show how we can combine phrase structure rules with semantic information. To represent meanings, I will use first-order predicate logic and λ-calculus. Unfortunately, it is not possible to provide a detailed discussion of the basics of logic so that even readers without prior knowledge can follow all the details, but the simple examples discussed here should be enough to provide some initial insights into how syntax and semantics interact and furthermore, how we can develop a linguistic theory to account for this.

To show how the meaning of a sentence is derived from the meaning of its parts, we will consider (18a). We assign the meaning in (18b) to the sentence in (18a).

(18) a. Max schläft.
Max sleeps
'Max is sleeping.'

b. *schlafen′*(*max′*)

Here, we are assuming *schlafen′* to be the meaning of *schläft* 'sleeps'. We use prime symbols to indicate that we are dealing with word meanings and not actual words. At first glance, it may not seem that we have really gained anything by using *schlafen′* to represent the meaning of (18a), since it is just another form of the verb *schläft* 'sleeps'. It is, however, important to concentrate on a single verb form as inflection is irrelevant when it comes to meaning. We can see this by comparing the examples in (19a) and (19b):

(19) a. Jeder Junge schläft.
every boy sleeps
'Every boy sleeps.'

b. Alle Jungen schlafen.
all boys sleep
'All boys sleep.'

When looking at the meaning in (18b), we can consider which part of the meaning comes from each word. It seems relatively intuitive that *max′* comes from *Max*, but the trickier question is what exactly *schläft* 'sleeps' contributes in terms of meaning. If we think

about what characterizes a 'sleeping' event, we know that there is typically an individual who is sleeping. This information is part of the meaning of the verb *schlafen* 'to sleep'. The verb meaning does not contain information about the sleeping individual, however, as this verb can be used with various subjects:

(20) a. Paul schläft.
Paul sleeps
'Paul is sleeping.'

b. Mio schläft.
Mio sleeps
'Mio is sleeping.'

c. Xaver schläft.
Xaver sleeps
'Xaver is sleeping.'

We can therefore abstract away from any specific use of *schlafen′* and instead of, for example, *max′* in (18b), we use a variable (e. g. x). This x can then be replaced by *paul′*, *mio′* or *xaver′* in a given sentence. To allow us to access these variables in a given meaning, we can write them with a λ in front. Accordingly, *schläft* 'sleeps' will have the following meaning:

(21) λx *sleep′*(x)

The step from (18b) to (21) is referred to as *lambda abstraction*. The combination of the expression (21) with the meaning of its arguments happens in the following way: we remove the λ and the corresponding variable and then replace all instances of the variable with the meaning of the argument. If we combine (21) and *max′* as in (22), we arrive at the meaning in (18b).

(22) λx *sleep′*(x) *max′*

The process is called β-reduction or λ-conversion. To show this further, let us consider an example with a transitive verb. The sentence in (23a) has the meaning given in (23b):

(23) a. Max mag Lotte.
Max likes Lotte
'Max likes Lotte.'

b. *like′*(*max′*, *lotte′*)

The λ-abstraction of *mag* 'likes' is shown in (24):

(24) $\lambda y \lambda x$ *like′*(x, y)

Note that it is always the first λ that has to be used first. The variable y corresponds to the object of *mögen*. For languages like English it is assumed that the object forms a verb phrase (VP) together with the verb and this VP is combined with the subject. German

differs from English in allowing more freedom in constituent order. The problems that result for form meaning mappings are solved in different ways by different theories. The respective solutions will be addressed in the following chapters.

If we combine the representation in (24) with that of the object *Lotte*, we arrive at (25a), and following β-reduction, (25b):

(25) a. $\lambda y \lambda x$ *like′*(x, y) *lotte′*
b. λx *like′*(x, *lotte′*)

This meaning can in turn be combined with the subject and we then get (26a) and (26b) after β-reduction:

(26) a. λx *like′*(x, *lotte′*) *max′*
b. *like′*(*max′*, *lotte′*)

After introducing lambda calculus, integrating the composition of meaning into our phrase structure rules is simple. A rule for the combination of a verb with its subject has to be expanded to include positions for the semantic contribution of the verb, the semantic contribution of the subject and then the meaning of the combination of these two (the entire sentence). The complete meaning is the combination of the individual meanings in the correct order. We can therefore take the simple rule in (27a) and turn it into (27b):

(27) a. S → NP(nom) V
b. S(V′ NP′) → NP(nom, NP′) V(V′)

V′ stands for the meaning of V and NP′ for the meaning of the NP(nom). V′ NP′ stands for the combination of V′ and NP′. When analyzing (18a), the meaning of V′ is λx schlafen(x) and the meaning of NP′ is *max′*. The combination of V′ NP′ corresponds to (28a) or after β-reduction to (18b) – repeated here as (28b):

(28) a. λx *sleep′*(x) *max′*
b. *sleep′*(*max′*)

For the example with a transitive verb in (23a), the rule in (29) can be proposed:

(29) S(V′ NP2′ NP1′) → NP(nom, NP1′) V(V′) NP(acc, NP2′)

The meaning of the verb (V′) is first combined with the meaning of the object (NP2′) and then with the meaning of the subject (NP1′).

At this point, we can see that there are several distinct semantic rules for the phrase structure rules above. The hypothesis that we should analyze language in this way is called the *rule-by-rule hypothesis* (Bach 1976). A more general process for deriving the meaning of linguistic expression will be presented in Section 5.1.4.

2.4 Phrase structure rules for some aspects of German syntax

Whereas determining the direct constituents of a sentence is relative easy, since we can very much rely on the movement test due to the somewhat flexible order of constituents in German, it is more difficult to identify the parts of the noun phrase. This is the problem we will focus on in this section. To help motivate assumptions about $\overline{\text{X}}$ syntax to be discussed in Section 2.5, we will also discuss prepositional phrases.

2.4.1 Noun phrases

Up to now, we have assumed a relatively simple structure for noun phrases: our rules state that a noun phrase consists of a determiner and a noun. Noun phrases can have a distinctly more complex structure than (30a). This is shown by the following examples in (30):

(30)
a. eine Frau
   a woman
b. eine Frau, die wir kennen
   a woman who we know
c. eine Frau aus Stuttgart
   a woman from Stuttgart
d. eine kluge Frau
   a smart woman
e. eine Frau aus Stuttgart, die wir kennen
   a woman from Stuttgart who we know
f. eine kluge Frau aus Stuttgart
   a smart woman from Stuttgart
g. eine kluge Frau, die wir kennen
   a smart woman who we know
h. eine kluge Frau aus Stuttgart, die wir kennen
   a smart woman from Stuttgart who we know

As well as determiners and nouns, noun phrases can also contain adjectives, prepositional phrases and relative clauses. The additional elements in (30) are adjuncts. They restrict the set of objects which the noun phrase refers to. Whereas (30a) refers to a being which has the property of being a woman, the referent of (30b) must also have the property of being known to us.

Our previous rules for noun phrases simply combined a noun and a determiner and can therefore only be used to analyze (30a). The question we are facing now is how we can modify this rule or which additional rules we would have to assume in order to

analyze the other noun phrases in (30). In addition to rule (31a), one could propose a rule such as the one in (31b).[5,6]

(31) a. NP → Det N
b. NP → Det A N

However, this rule would still not allow us to analyze noun phrases such as (32):

(32) alle weiteren schlagkräftigen Argumente
all further strong arguments
'all other strong arguments'

In order to be able to analyze (32), we require a rule such as (33):

(33) NP → Det A A N

It is always possible to increase the number of adjectives in a noun phrase and setting an upper limit for adjectives would be entirely arbitrary. Even if we opt for the following abbreviation, there are still problems:

(34) NP → Det A* N

The asterisk in (34) stands for any number of iterations. Therefore, (34) encompasses rules with no adjectives as well as those with one, two or more.

The problem is that according to the rule in (34) adjectives and nouns do not form a constituent and we can therefore not explain why coordination is still possible in (35):

(35) alle [[geschickten Kinder] und [klugen Frauen]]
all skillful children and smart women
'all the skillful children and smart women'

If we assume that coordination involves the combination of two or more word strings with the same syntactic properties, then we would have to assume that the adjective and noun form a unit.

The noun phrases with adjectives discussed thus far can be explained by the following rules:

(36) a. NP → Det $\overline{\text{N}}$
b. $\overline{\text{N}}$ → A $\overline{\text{N}}$
c. $\overline{\text{N}}$ → N

These rules state the following: a noun phrase consists of a determiner and a nominal element ($\overline{\text{N}}$). This nominal element can consist of an adjective and a nominal element (36b), or just a noun (36c). Since $\overline{\text{N}}$ is also on the right-hand side of the rule in (36b), we can apply this rule multiple times and therefore account for noun phrases with multiple adjectives such as (32). Figure 2.3 on the next page shows the structure of a noun phrase

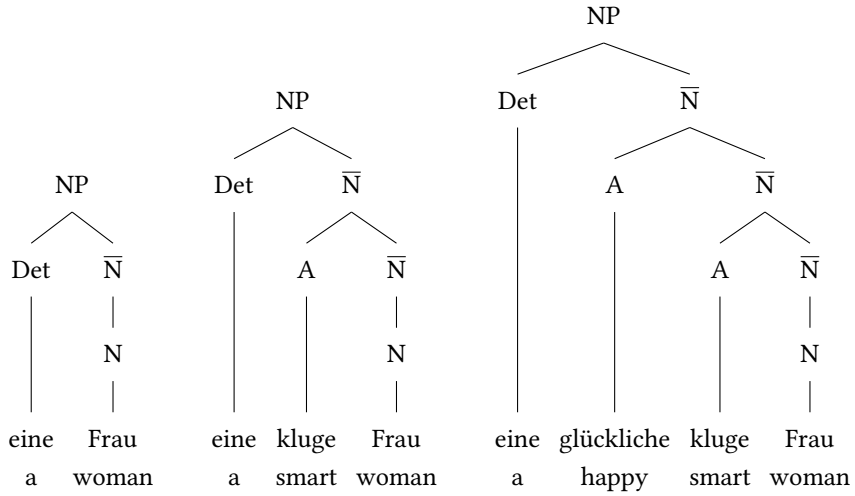

Figure 2.3: Noun phrases with differing numbers of adjectives

without an adjective and that of a noun phrase with one or two adjectives. The adjective *klug* 'smart' restricts the set of referents for the noun phrase. If we assume an additional adjective such as *glücklich* 'happy', then it only refers to those women who are happy as well as smart. These kinds of noun phrases can be used in contexts such as the following:

(37) A: Alle klugen Frauen sind unglücklich.
all smart women are unhappy
B: Nein, ich kenne eine glückliche kluge Frau.
no I know a happy smart woman

We observe that this discourse can be continued with *Aber alle glücklichen klugen Frauen sind schön* 'but all happy, smart women are beautiful' and a corresponding answer. The possibility to have even more adjectives in noun phrases such as *eine glückliche kluge Frau* 'a happy, smart woman' is accounted for in our rule system in (36). In the rule (36b), $\overline{\text{N}}$ occurs on the left as well as the right-hand side of the rule. This kind of rule is referred to as *recursive*.

We have now developed a nifty little grammar that can be used to analyze noun phrases containing adjectival modifiers. As a result, the combination of an adjective and noun is given constituent status. One may wonder at this point if it would not make sense to also assume that determiners and adjectives form a constituent, as we also have the following kind of noun phrases:

[5] See Eisenberg (2004: 238) for the assumption of flat structures in noun phrases.
[6] There are, of course, other features such as gender and number, which should be part of all the rules discussed in this section. I have omitted these in the following for ease of exposition.

(38) diese schlauen und diese neugierigen Frauen
these smart and these curious women

Here, we are dealing with a different structure, however. Two full NPs have been conjoined and part of the first conjunct has been deleted.

(39) diese schlauen ~~Frauen~~ und diese neugierigen Frauen
these smart women and these curious women

One can find similar phenomena at the sentence and even word level:

(40) a. dass Peter dem Mann das Buch ~~gibt~~ und Maria der Frau die Schallplatte
that Peter the man the book gives and Maria the woman the record
gibt
gives
'that Peters gives the book to the man and Maria the record to the woman'

b. be- und ent-laden
PRT and PRT-load
'load and unload'

Thus far, we have discussed how we can ideally integrate adjectives into our rules for the structure of noun phrases. Other adjuncts such as prepositional phrases or relative clauses can be combined with $\overline{\text{N}}$ in an analogous way to adjectives:

(41) a. $\overline{\text{N}} \rightarrow \overline{\text{N}}$ PP
b. $\overline{\text{N}} \rightarrow \overline{\text{N}}$ relative clause

With these rules and those in (36), it is possible – assuming the corresponding rules for PPs and relative clauses – to analyze all the examples in (30).

(36c) states that it is possible for $\overline{\text{N}}$ to consist of a single noun. A further important rule has not yet been discussed: we need another rule to combine nouns such as *Vater* 'father', *Sohn* 'son' or *Bild* 'picture', so-called *relational nouns*, with their arguments. Examples of these can be found in (42a–b). (42c) is an example of a nominalization of a verb with its argument:

(42) a. der Vater von Peter
the father of Peter
'Peter's father'

b. das Bild vom Gleimtunnel
the picture of.the Gleimtunnel
'the picture of the Gleimtunnel'

c. das Kommen des Installateurs
the coming of.the plumber
'the plumber's visit'

The rule that we need to analyze (42a,b) is given in (43):

(43) $\overline{\text{N}} \rightarrow \text{N PP}$

Figure 2.4 shows two structures with PP-arguments. The tree on the right also contains an additional PP-adjunct, which is licensed by the rule in (41a).

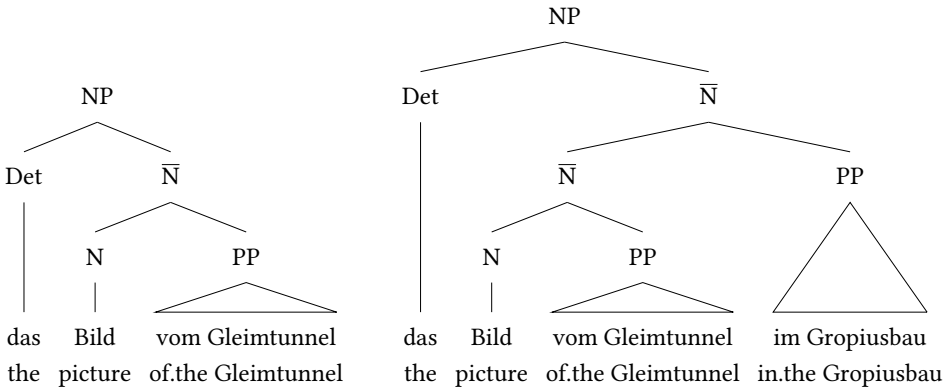

Figure 2.4: Combination of a noun with PP complement *vom Gleimtunnel* to the right with an adjunct PP

In addition to the previously discussed NP structures, there are other structures where the determiner or noun is missing. Nouns can be omitted via ellipsis. (44) gives an example of noun phrases, where a noun that does not require a complement has been omitted. The examples in (45) show NPs in which only one determiner and complement of the noun has been realized, but not the noun itself:

(44) a. eine kluge _
a smart
'a smart one'

b. eine kluge große _
a smart tall
'a smart tall one'

c. eine kluge _ aus Hamburg
a smart from Hamburg
'a smart one from Hamburg'

d. eine kluge _, die alle kennen
a smart who everyone knows
'a smart one who everyone knows'

(45) a. (Nein, nicht der Vater von Klaus), der _ von Peter war gemeint.
no not the father of Klaus the of Peter was meant
'No, it wasn't the father of Klaus, but rather the one of Peter that was meant.'

b. (Nein, nicht das Bild von der Stadtautobahn), das _ vom Gleimtunnel
no not the picture of the motorway the of.the Gleimtunnel
war beeindruckend.
was impressive
'No, it wasn't the picture of the motorway, but rather the one of the Gleimtunnel that was impressive.'

c. (Nein, nicht das Kommen des Tischlers), das _ des Installateurs ist
no not the coming of.the carpenter the of.the plumber is
wichtig.
important
'No, it isn't the visit of the carpenter, but rather the visit of the plumber that is important.'

The underscore marks the position where the noun would normally occur. In English, the pronoun *one* must often be used in the corresponding position, but in German the noun is simply omitted. (See Fillmore, Lee-Goldmann & Rhomieux (2012: Section 4.12) for English examples without the pronoun *one*.) In phrase structure grammars, this can be described by a so-called *epsilon production*. These rules replace a symbol with nothing (46a). The rule in (46b) is an equivalent variant which is responsible for the term *epsilon production*:

(46) a. $N \rightarrow$
b. $N \rightarrow \epsilon$

The corresponding trees are shown in Figure 2.5. Going back to boxes, the rules in (46)

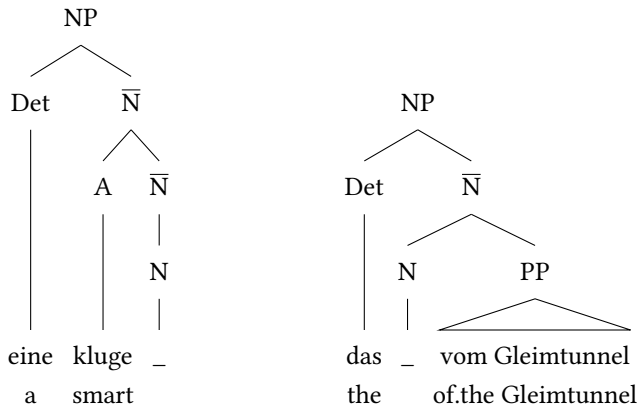

Figure 2.5: Noun phrases without an overt head

correspond to empty boxes with the same labels as the boxes of ordinary nouns. As we

have considered previously, the actual content of the boxes is unimportant when considering the question of where we can incorporate them. In this way, the noun phrases in (30) can occur in the same sentences. The empty noun box also behaves like one with a genuine noun. If we do not open the empty box, we will not be able to ascertain the difference to a filled box.

It is not only possible to omit the noun from noun phrases, but the determiner can also remain unrealized in certain contexts. (47) shows noun phrases in plural:

(47) a. Frauen
women

b. Frauen, die wir kennen
women who we know

c. kluge Frauen
smart women

d. kluge Frauen, die wir kennen
smart women who we know

The determiner can also be omitted in singular if the noun denotes a mass noun:

(48) a. Getreide
grain

b. Getreide, das gerade gemahlen wurde
grain that just ground was
'grain that has just been ground'

c. frisches Getreide
fresh grain

d. frisches Getreide, das gerade gemahlen wurde
fresh grain that just ground was
'fresh grain that has just been ground'

Finally, both the determiner and the noun can be omitted:

(49) a. Ich helfe klugen.
I help smart
'I help smart ones.'

b. Dort drüben steht frisches, das gerade gemahlen wurde.
there over stands fresh that just ground was
'Over there is some fresh (grain) that has just been ground.'

Figure 2.6 on the next page shows the corresponding trees.

It is necessary to add two further comments to the rules we have developed up to this point: up to now, I have always spoken of adjectives. However, it is possible to have very complex adjective phrases in pre-nominal position. These can be adjectives with complements (50a,b) or adjectival participles (50c,d):

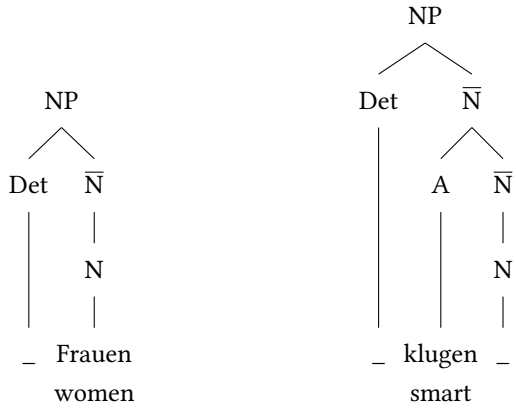

Figure 2.6: Noun phrases without overt determiner

(50) a. der seiner Frau treue Mann
the his.DAT wife faithful man
'the man faithful to his wife'

b. der auf seinen Sohn stolze Mann
the on his.ACC son proud man
'the man proud of his son'

c. der seine Frau liebende Mann
the his.ACC woman loving man
'the man who loves his wife'

d. der von seiner Frau geliebte Mann
the by his.DAT wife loved man
'the man loved by his wife'

Taking this into account, the rule (36b) has to be modified in the following way:

(51) $\overline{N} \rightarrow AP\ \overline{N}$

An adjective phrase (AP) can consist of an NP and an adjective, a PP and an adjective or just an adjective:

(52) a. $AP \rightarrow NP\ A$
b. $AP \rightarrow PP\ A$
c. $AP \rightarrow A$

There are two imperfections resulting from the rules we have developed thus far. These are the rules for adjectives or nouns without complements in (52c) as well as (36c) – repeated here as (53):

(53) $\overline{\text{N}} \rightarrow \text{N}$

If we apply these rules, then we will generate unary branching subtrees, that is trees with a mother that only has one daughter. See Figure 2.6 for an example of this. If we maintain the parallel to the boxes, this would mean that there is a box which contains another box which is the one with the relevant content.

In principle, nothing stops us from placing this information directly into the larger box. Instead of the rules in (54), we will simply use the rules in (55):

(54) a. $\text{A} \rightarrow$ kluge
b. $\text{N} \rightarrow$ Mann

(55) a. $\text{AP} \rightarrow$ kluge
b. $\overline{\text{N}} \rightarrow$ Mann

(55a) states that *kluge* 'smart' has the same properties as a full adjective phrase, in particular that it cannot be combined with a complement. This is parallel to the categorization of the pronoun *er* 'he' as an NP in the grammars (2) and (6).

Assigning $\overline{\text{N}}$ to nouns which do not require a complement has the advantage that we do not have to explain why the analysis in (56b) is possible as well as (56a) despite there not being any difference in meaning.

(56) a. [$_{\text{NP}}$ einige [$_{\overline{\text{N}}}$ kluge [$_{\overline{\text{N}}}$ [$_{\overline{\text{N}}}$ [$_{\text{N}}$ Frauen] und [$_{\overline{\text{N}}}$ [$_{\text{N}}$ Männer]]]]]]
some smart women and men

b. [$_{\text{NP}}$ einige [$_{\overline{\text{N}}}$ kluge [$_{\overline{\text{N}}}$ [$_{\text{N}}$ [$_{\text{N}}$ Frauen] und [$_{\text{N}}$ Männer]]]]]
some smart women and men

In (56a), two nouns have projected to $\overline{\text{N}}$ and have then been joined by coordination. The result of coordination of two constituents of the same category is always a new constituent with that category. In the case of (56a), this is also $\overline{\text{N}}$. This constituent is then combined with the adjective and the determiner. In (56b), the nouns themselves have been coordinated. The result of this is always another constituent which has the same category as its parts. In this case, this would be N. This N becomes $\overline{\text{N}}$ and is then combined with the adjective. If nouns which do not require complements were categorized as $\overline{\text{N}}$ rather than N, we would not have the problem of spurious ambiguities. The structure in (57) shows the only possible analysis.

(57) [$_{\text{NP}}$ einige [$_{\overline{\text{N}}}$ kluge [$_{\overline{\text{N}}}$ [$_{\overline{\text{N}}}$ Frauen] und [$_{\overline{\text{N}}}$ Männer]]]]
some smart women and men

2.4.2 Prepositional phrases

Compared to the syntax of noun phrases, the syntax of prepositional phrases (PPs) is relatively straightforward. PPs normally consist of a preposition and a noun phrase whose case is determined by that preposition. We can capture this with the following rule:

(58) PP → P NP

This rule must, of course, also contain information about the case of the NP. I have omitted this for ease of exposition as I did with the NP-rules and AP-rules above.

The Duden grammar (Eisenberg et al. 2005: §1300) offers examples such as those in (59), which show that certain prepositional phrases serve to further define the semantic contribution of the preposition by indicating some measurement, for example:

(59) a. [[Einen Schritt] vor dem Abgrund] blieb er stehen.
one step before the abyss remained he stand
'He stopped one step in front of the abyss.'

b. [[Kurz] nach dem Start] fiel die Klimaanlage aus.
shortly after the take.off fell the air.conditioning out
'Shortly after take off, the air conditioning stopped working.'

c. [[Schräg] hinter der Scheune] ist ein Weiher.
diagonally behind the barn is a pond
'There is a pond diagonally across from the barn.'

d. [[Mitten] im Urwald] stießen die Forscher auf einen alten Tempel.
middle in.the jungle stumbled the researchers on an old temple
'In the middle of the jungle, the researches came across an old temple.'

To analyze the sentences in (59a,b), one could propose the following rules in (60):

(60) a. PP → NP PP
b. PP → AP PP

These rules combine a PP with an indication of measurement. The resulting constituent is another PP. It is possible to use these rules to analyze prepositional phrases in (59a,b), but it unfortunately also allows us to analyze those in (61):

(61) a. * [PP einen Schritt [PP kurz [PP vor dem Abgrund]]]
one step shortly before the abyss

b. * [PP kurz [PP einen Schritt [PP vor dem Abgrund]]]
shortly one step before the abyss

Both rules in (60) were used to analyze the examples in (61). Since the symbol PP occurs on both the left and right-hand side of the rules, we can apply the rules in any order and as many times as we like.

We can avoid this undesired side-effect by reformulating the previously assumed rules:

(62) a. PP → NP $\overline{\text{P}}$
b. PP → AP $\overline{\text{P}}$
c. PP → $\overline{\text{P}}$

d. $\overline{\text{P}} \rightarrow \text{P NP}$

Rule (58) becomes (62d). The rule in (62c) states that a PP can consist of $\overline{\text{P}}$. Figure 2.7 shows the analysis of (63) using (62c) and (62d) as well as the analysis of an example with an adjective in the first position following the rules in (62b) and (62d):

(63) vor dem Abgrund
before the abyss
'in front of the abyss'

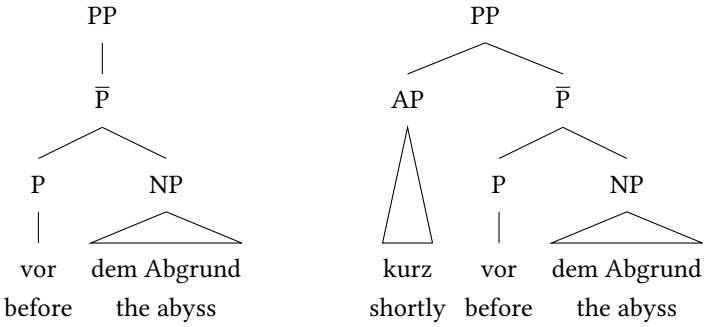

Figure 2.7: Prepositional phrases with and without measurement

At this point, the attentive reader is probably wondering why there is no empty measurement phrase in the left figure of Figure 2.7, which one might expect in analogy to the empty determiner in Figure 2.6. The reason for the empty determiner in Figure 2.6 is that the entire noun phrase without the determiner has a meaning similar to those with a determiner. The meaning normally contributed by the visible determiner has to somehow be incorporated in the structure of the noun phrase. If we did not place this meaning in the empty determiner, this would lead to more complicated assumptions about semantic combination: we only really require the mechanisms presented in Section 2.3 and these are very general in nature. The meaning is contributed by the words themselves and not by any rules. If we were to assume a unary branching rule such as that in the left tree in Figure 2.7 instead of the empty determiner, then this unary branching rule would have to provide the semantics of the determiner. This kind of analysis has also been proposed by some researchers. See Chapter 19 for more on empty elements.

Unlike determiner-less NPs, prepositional phrases without an indication of degree or measurement do not lack any meaning component for composition. It is therefore not necessary to assume an empty indication of measurement, which somehow contributes to the meaning of the entire PP. Hence, the rule in (62c) states that a prepositional phrase consists of $\overline{\text{P}}$, that is, a combination of P and NP.

2.5 $\overline{\text{X}}$ theory

If we look again at the rules that we have formulated in the previous section, we see that heads are always combined with their complements to form a new constituent (64a,b), which can then be combined with further constituents (64c,d):

(64) a. $\overline{\text{N}} \rightarrow \text{N PP}$
b. $\overline{\text{P}} \rightarrow \text{P NP}$
c. $\text{NP} \rightarrow \text{Det } \overline{\text{N}}$
d. $\text{PP} \rightarrow \text{NP } \overline{\text{P}}$

Grammarians working on English noticed that parallel structures can be used for phrases which have adjectives or verbs as their head. I discuss adjective phrases at this point and postpone the discussion of verb phrases to Chapter 3. As in German, certain adjectives in English can take complements with the important restriction that adjective phrases with complements cannot realize these pre-nominally in English. (65) gives some examples of adjective phrases:

(65) a. He is proud.
b. He is very proud.
c. He is proud of his son.
d. He is very proud of his son.

Unlike prepositional phrases, complements of adjectives are normally optional. *proud* can be used with or without a PP. The degree expression *very* is also optional.

The rules which we need for this analysis are given in (66), with the corresponding structures in Figure 2.8 on the next page.

(66) a. $\text{AP} \rightarrow \overline{\text{A}}$
b. $\text{AP} \rightarrow \text{AdvP } \overline{\text{A}}$
c. $\overline{\text{A}} \rightarrow \text{A PP}$
d. $\overline{\text{A}} \rightarrow \text{A}$

As was shown in Section 2.2, it is possible to generalize over very specific phrase structure rules and thereby arrive at more general rules. In this way, properties such as person, number and gender are no longer encoded in the category symbols, but rather only simple symbols such as NP, Det and N are used. It is only necessary to specify something about the values of a feature if it is relevant in the context of a given rule. We can take this abstraction a step further: instead of using explicit category symbols such as N, V, P and A for lexical categories and NP, VP, PP and AP for phrasal categories, one can simply use a variable for the word class in question and speak of X and XP.

This form of abstraction can be found in so-called $\overline{\text{X}}$ theory (or X-bar theory, the term *bar* refers to the line above the symbol.), which was developed by Chomsky (1970) and refined by Jackendoff (1977). This form of abstract rules plays an important role in many

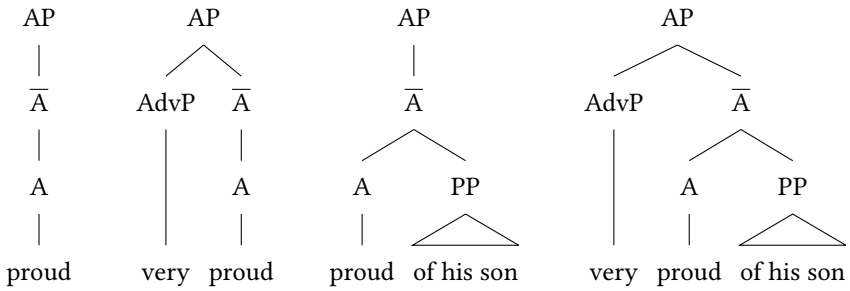

Figure 2.8: English adjective phrases

different theories. For example: Government & Binding (Chapter 3), Generalized Phrase Structure Grammar (Chapter 5) and Lexical Functional Grammar (Chapter 7). In HPSG (Chapter 9), $\overline{X}$ theory also plays a role, but not all restrictions of the $\overline{X}$ schema have been adopted.

(67) shows a possible instantiation of $\overline{X}$ rules, where the category X has been used in place of N, as well as examples of word strings which can be derived by these rules:

(67)	$\overline{X}$ rule	with specific categories	example strings
	$\overline{\overline{X}} \rightarrow \overline{\overline{\text{specifier}}}\ \overline{X}$	$\overline{\overline{N}} \rightarrow \overline{\overline{\text{DET}}}\ \overline{N}$	the [picture of Paris]
	$\overline{X} \rightarrow \overline{X}\ \overline{\overline{\text{adjunct}}}$	$\overline{N} \rightarrow \overline{N}\ \overline{\overline{\text{REL\_CLAUSE}}}$	[picture of Paris] [that everybody knows]
	$\overline{X} \rightarrow \overline{\overline{\text{adjunct}}}\ \overline{X}$	$\overline{N} \rightarrow \overline{\overline{A}}\ \overline{N}$	beautiful [picture of Paris]
	$\overline{X} \rightarrow X\ \overline{\overline{\text{complement}}*}$	$\overline{N} \rightarrow N\ \overline{\overline{P}}$	picture [of Paris]

Any word class can replace X (e. g. V, A or P). The X without the bar stands for a lexical item in the above rules. If one wants to make the bar level explicit, then it is possible to write X^0. Just as with the rule in (15), where we did not specify the case value of the determiner or the noun but rather simply required that the values on the right-hand side of the rule match, the rules in (67) require that the word class of an element on the right-hand side of the rule (X or $\overline{X}$) matches that of the element on the left-hand side of the rule ($\overline{X}$ or $\overline{\overline{X}}$).

A lexical element can be combined with all its complements. The '*' in the last rule stands for an unlimited amount of repetitions of the symbol it follows. A special case is zerofold occurrence of complements. There is no PP complement of *Bild* 'picture' present in *das Bild* 'the picture' and thus N becomes $\overline{N}$. The result of the combination of a lexical element with its complements is a new projection level of X: the projection level 1, which is marked by a bar. $\overline{X}$ can then be combined with adjuncts. These can occur to the left or right of $\overline{X}$. The result of this combination is still $\overline{X}$, that is the projection level is not changed by combining it with an adjunct. Maximal projections are marked by two bars. One can also write XP for a projection of X with two bars. An XP consists of a specifier

and $\overline{\text{X}}$. Depending on one's theoretical assumptions, subjects of sentences (Haider 1995, 1997a; Berman 2003a: Section 3.2.2) and determiners in NPs (Chomsky 1970: 210) are specifiers. Furthermore, degree modifiers (Chomsky 1970: 210) in adjective phrases and measurement indicators in prepositional phrases are also counted as specifiers.

Non-head positions can only host maximal projections and therefore complements, adjuncts and specifiers always have two bars. Figure 2.9 gives an overview of the minimal and maximal structure of phrases.

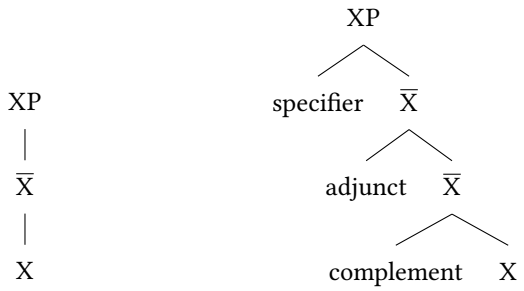

Figure 2.9: Minimal and maximal structure of phrases

Some categories do not have a specifier or have the option of having one. Adjuncts are optional and therefore not all structures have to contain an $\overline{\text{X}}$ with an adjunct daughter. In addition to the branching shown in the right-hand figure, adjuncts to XP and head-adjuncts are sometimes possible. There is only a single rule in (67) for cases in which a head precedes the complements, however an order in which the complement precedes the head is of course also possible. This is shown in Figure 2.9.

Figure 2.10 on the next page shows the analysis of the NP structures *das Bild* 'the picture' and *das schöne Bild von Paris* 'the beautiful picture of Paris'. The NP structures in Figure 2.10 and the tree for *proud* in Figure 2.8 show examples of minimally populated structures. The left tree in Figure 2.10 is also an example of a structure without an adjunct. The right-hand structure in Figure 2.10 is an example for the maximally populated structure: specifier, adjunct, and complement are present.

The analysis given in Figure 2.10 assumes that all non-heads in a rule are phrases. One therefore has to assume that there is a determiner phrase even if the determiner is not combined with other elements. The unary branching of determiners is not elegant but it is consistent.[7] The unary branchings for the NP *Paris* in Figure 2.10 may also seem somewhat odd, but they actually become more plausible when one considers more complex noun phrases:

[7] For an alternative version of $\overline{\text{X}}$ theory which does not assume elaborate structure for determiners see Muysken (1982a).

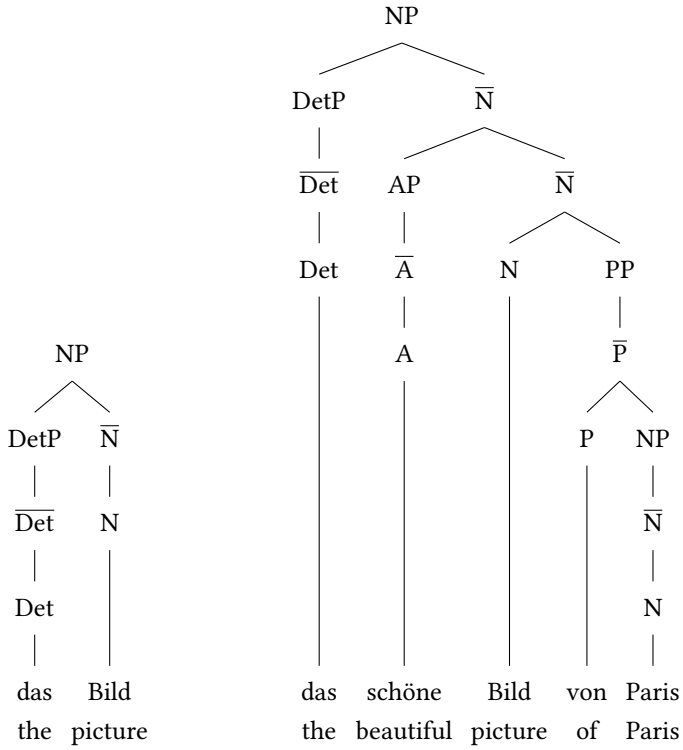

Figure 2.10: $\overline{\text{X}}$ analysis of *das Bild* 'the picture' and *das schöne Bild von Paris* 'the beautiful picture of Paris'

(68) a. das Paris der dreißiger Jahre
the Paris of.the thirty years
'30's Paris'

b. die Maria aus Hamburg
the Maria from Hamburg
'Maria from Hamburg'

Unary projections are somewhat inelegant but this should not concern us too much here, as we have already seen in the discussion of the lexical entries in (55) that unary branching nodes can be avoided for the most part and that it is indeed desirable to avoid such structures. Otherwise, one gets spurious ambiguities. In the following chapters, we will discuss approaches such as Categorial Grammar and HPSG, which do not assume unary rules for determiners, adjectives and nouns.

Furthermore, other $\overline{\text{X}}$ theoretical assumptions will not be shared by several theories discussed in this book. In particular, the assumption that non-heads always have to

be maximal projections will be disregarded. Pullum (1985) and Kornai & Pullum (1990) have shown that the respective theories are not necessarily less restrictive than theories which adopt a strict version of the $\overline{X}$ theory. See also the discussion in Section 13.1.2.

Comprehension questions

1. Why are phrase structure grammars that use only atomic categories inadequate for the description of natural languages?
2. Assuming the grammar in (6), state which steps (replacing symbols) one has to take to get to the symbol V in the sentence (69).

   (69) er das Buch dem Mann gibt
   he the book the man gives
   'He gives the book to the man.'

   Your answer should resemble the analysis in (3).
3. Give a representation of the meaning of (70) using predicate logic:

   (70) a. Ulrike kennt Hans.
   Ulrike knows Hans
   b. Joshi freut sich.
   Joshi is.happy REFL
   'Joshi is happy.'

Exercises

1. On page 57, I claimed that there is an infinite number of grammars we could use to analyze (1). Why is this claim correct?
2. Try to come up with some ways in which we can tell which of these possible grammars is or are the best?
3. A fragment for noun phrase syntax was presented in Section 2.4.1. Why is the interaction of the rules in (71) problematic?

   (71) a. $NP \rightarrow Det\ \overline{N}$
   b. $\overline{N} \rightarrow N$
   c. $Det \rightarrow \epsilon$
   d. $N \rightarrow \epsilon$
4. Why is it not a good idea to mark *books* as NP in the lexicon?

5. Can you think of some reasons why it is not desirable to assume the following rule for nouns such as *books*:

   (72) NP → Modifier* books Modifier*

   The rule in (72) combines an unlimited number of modifiers with the noun *books* followed by an unlimited number of modifiers. We can use this rule to derive phrases such as those in (73):

   (73) a. books
   b. interesting books
   c. interesting books from Stuttgart

   Make reference to coordination data in your answer. Assume that symmetric coordination requires that both coordinated phrases or words have the same syntactic category.

6. Fillmore et al. (2012) suggested treating nounless structures like those in (74) as involving a phrasal construction that combines the determiner *the* with an adjective.

   (74) a. Examine the plight of the very poor.
   b. Their outfits range from the flamboyant to the functional.
   c. The unimaginable happened.

   (75) shows a phrase structure rule that corresponds to their construction:

   (75) NP → the Adj

   Adj stands for something that can be a single word like *poor* or complex like *very poor*.

   Revisit the German data in (44) and (45) and explain why such an analysis and even a more general one as in (76) would not extend to German.

   (76) NP → Det Adj

7. Why can $\overline{X}$ theory not account for German adjective phrases without additional assumptions? (This task is for (native) speakers of German only.)

8. Come up with a phrase structure grammar that can be used to analyze the sentence in (77), but also rules out the sentences in (78).

(77) a. Der Mann hilft der Frau.
the.NOM man helps the.DAT woman
'The man helps the woman.'

b. Er gibt ihr das Buch.
he.NOM gives her.DAT the book
'He gives her the book.'

c. Er wartet auf ein Wunder.
he.NOM waits on a miracle
'He is waiting for a miracle.'

(78) a. * Der Mann hilft er.
the.NOM man helps he.NOM

b. * Er gibt ihr den Buch.
he.NOM gives her.DAT the.M book.N

9. Consider which additional rules would have to be added to the grammar you developed in the previous exercise in order to be able to analyze the sentences in (79):

(79) a. Der Mann hilft der Frau jetzt.
the.NOM man helps the.DAT woman now
'The man helps the woman now.'

b. Der Mann hilft der Frau neben dem Bushäuschen.
the.NOM man helps the.DAT woman next to.the bus.shelter
'The man helps the woman next to the bus shelter.'

c. Er gibt ihr das Buch jetzt.
he.NOM gives her.DAT the.ACC book now
'He gives her the book now.'

d. Er gibt ihr das Buch neben dem Bushäuschen.
he.NOM gives her.DAT the.ACC book next to.the bus.shelter
'He gives her the book next to the bus shelter.'

e. Er wartet jetzt auf ein Wunder.
he.NOM waits now on a miracle
'He is waiting for a miracle now.'

f. Er wartet neben dem Bushäuschen auf ein Wunder.
he.NOM waits next to.the.DAT bus.shelter on a miracle
'He is waiting for a miracle next to the bus shelter.'

10. Install a Prolog system (e. g. SWI-Prolog[8]) and try out your grammar. Details for the notation can be found in the corresponding handbook under the key word Definite Clause Grammar (DCG).

Further reading

The expansion of phrase structure grammars to include features was proposed as early as 1963 by Harman (1963).

The phrase structure grammar for noun phrases discussed in this chapter covers a large part of the syntax of noun phrases but cannot explain certain NP structures. Furthermore, it has the problem, which exercise 3 is designed to show. A discussion of these phenomena and a solution in the framework of HPSG can be found in Netter (1998) and Kiss (2005).

The discussion of the integration of semantic information into phrase structure grammars was very short. A detailed discussion of predicate logic and its integration into phrase structure grammars – as well as a discussion of quantifier scope – can be found in Blackburn & Bos (2005).

[8] http://www.swi-prolog.org/