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Syntax & Semantics WiSe 2022/2023

Lecture 9: $\overline{\text{X}}$ Theory

24/11/2022, Christian Bentz

Overview

Adjectives or Adverbs?

The Duden grammar (Eisenberg et al. 2005: §1300) offers examples such as those in (60), which show that certain prepositional phrases serve to further define the semantic contribution of the preposition by indicating some measurement, for example:

(60) 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 (60a,b), one could propose the following rules in (61):

(61) a. PP → NP PP

b. PP → AP PP

Müller (2019), p. 72.

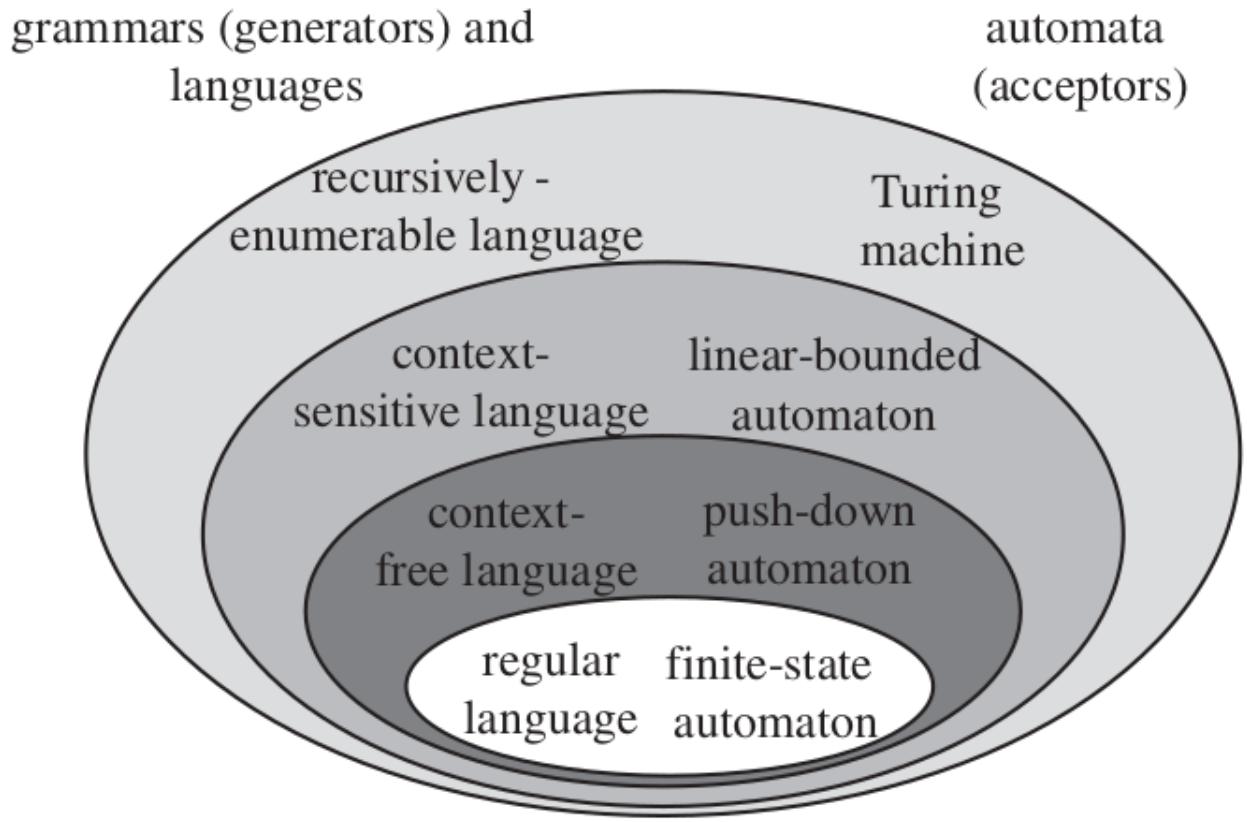
Section 1: Recap of Lecture 8

Natural Language Examples

$$\alpha \rightarrow \beta$$
$$\text{the} \rightarrow \text{a}$$
$$\text{the tree} \rightarrow \text{this}$$
$$\text{the huge tree} \rightarrow \text{the tree}$$
$$\text{the huge tree bends in the wind} \rightarrow \text{the}$$
$$\text{the} \rightarrow \text{the huge tree bends in the wind}$$
$$\text{VP} \rightarrow \text{NP bends NP NP}$$
$$\text{NP VP NP NP} \rightarrow \text{NP VP}$$
$$\text{DET} \rightarrow \text{the}$$
$$\text{the} \rightarrow \text{DET}$$
$$\text{NP} \rightarrow \text{the N}$$
$$\text{NP} \rightarrow \text{DET N}$$
$$\text{VP} \rightarrow \text{NP VP}$$

In a series of publications, Chomsky (1956, 1957, 1959, 1963) and Chomsky & Schützenberger (1965) discussed which *further restrictions* to re-write rules could be applied to more realistically match the generative capacity of natural languages.

The Classical Hierarchy



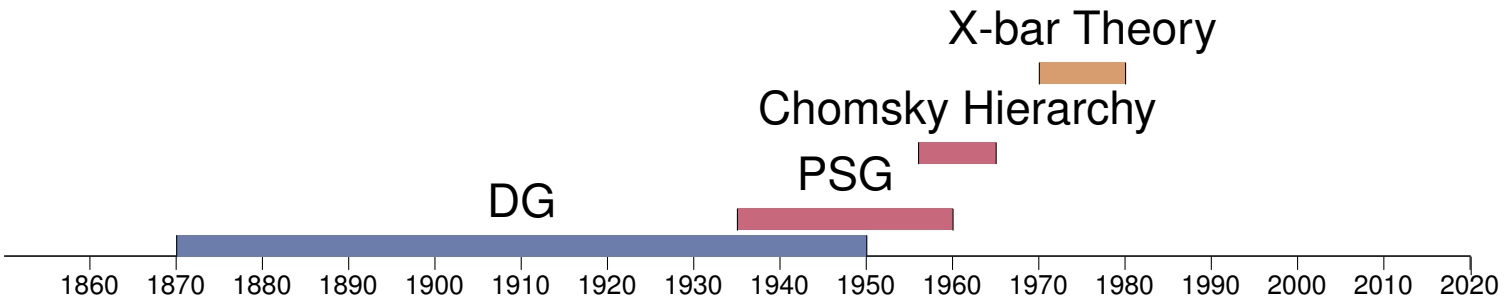
Fitch & Friederici (2012).

Section 2: Historical Notes

Historical Perspective

"[...] so-called $\overline{X}$ 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 different theories. For example: Government & Binding (Chapter 3), Generalized Phrase Structure Grammar (Chapter 5) and Lexical Functional Grammar (Chapter 7)."

Müller (2019). Grammatical theory, p. 75.

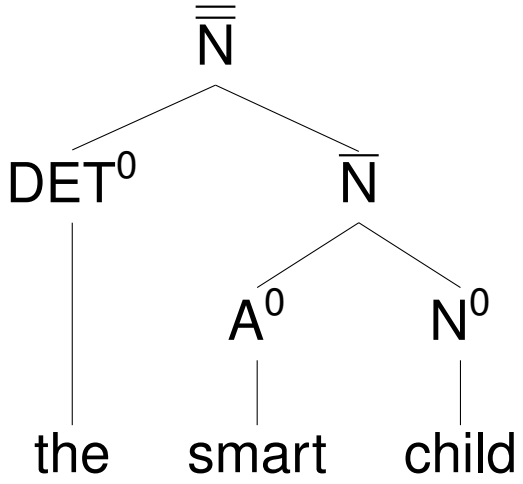


Note: The chronology bars indicate the rough time period where the first and foundational works relating to a framework were published. All of the theories discussed here still have repercussions also in current syntactic research.

Section 3: Basic Definitions

The bar(s) in X-bar theory

The bar is simply a notational convention to indicate the **level or position of a symbol** in the phrase structure tree – in relation to the level of the symbol that it is dominated by.



Equivalent Notations:

$\overline{\overline{N}}$ = NP

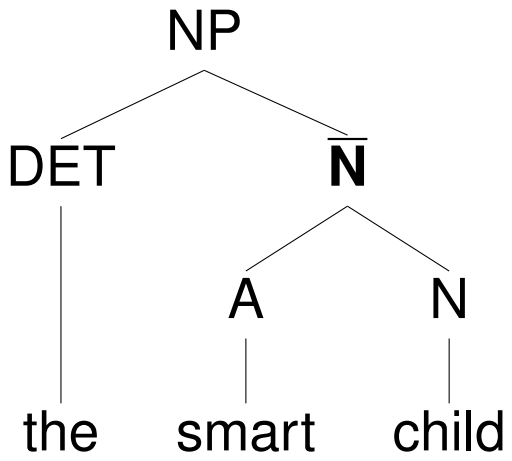
$\overline{N}$ = NP or N

N^0 = N (of terminal rewrite)

Note: The bars represent so-called *projection levels*. Level 0 (no bar), level 1 (one bar), level 2 (two bars).

Beware the Notational Confusion

In Müller (2019) – and other publications working on this framework – the most frequent convention is to only use bars for the symbols in between the highest level phrase and the symbols leading to the terminals. For highest level phrases the phrase notation is used (e.g. NP), and for the terminal level the zero is dropped. We will adopt this notation in this lecture as well.



Equivalent Notations:

$\bar{\bar{N}}$ = NP

$\bar{N}$ = NP or N

N^0 = N (of terminal rewrite)

Why do we need bars in the first place?

Natural languages are arguably **infinite in their productive potential**. To capture this productivity, we need some structure in our rewrite rules that allows for infinite productivity. For example, we could use the so-called *Kleene star* <*>.

Sentences:	**Rule:**	**Creates:**
(1) a child	NP $\rightarrow$ DET N	(1)
(2) a smart child	NP $\rightarrow$ DET A N	(2)
(3) a smart, diligent child	NP $\rightarrow$ DET A A N	(3)
(4) a smart, diligent, quiet, etc. child	NP $\rightarrow$ DET A* N	(1), (2), (3), (4)[1]

[1]The Kleene star allows for anything from 0 to ∞ realizations of A.

Why do we need bars in the first place?

However, the problem with the rewrite rule involving the Kleene star[1] is that the adjective-noun combination is not handeled as a constituent by itself, since the determiner is required by the rewrite rule. This rewrite rule hence excludes coordination involving adjective-noun phrases without the determiner.[2]

Sentences:	**Rule:**
(5) all [[the smart children] and [the diligent people]]	NP $\rightarrow$ [DET A* N]
(6) all [[smart children] and [diligent people]]	NP $\rightarrow$ DET [A* N]

[1] Some theories would also consider it a problem that the rule does not adhere to the binarization constraint.

[2] The problem could also be solved by allowing empty determiners, i.e. $DET \rightarrow \epsilon$, but then we would always have to posit an empty determiner when only adjective-noun combinations are used.

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The Noun Phrase

Why do we need bars in the first place?

The solution to capture all the noun phrases discussed above is a set of rewrite rules using the bar notation:[3]

1. NP $\rightarrow$ DET $\overline{\text{N}}$
2. NP $\rightarrow$ $\overline{\text{N}}$ [4]
3. $\overline{\text{N}}$ $\rightarrow$ AP $\overline{\text{N}}$ [5]
4. $\overline{\text{N}}$ $\rightarrow$ N

Müller (2019). Grammatical theory, p. 64.

[3] These rewrite rules also adhere to the binarization constraint but they wouldn't have to.

[4] This rule accounts for the fact that sometimes NPs don't have determiners, e.g. *smart children read books*.

[5] We have generalized A to AP here, since whole adjective phrases are also possible in these positions, e.g. *the very smart, very diligent child*.

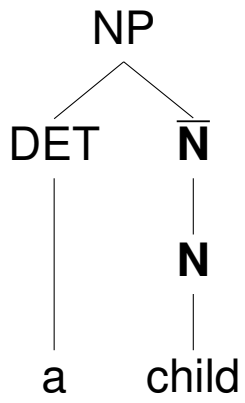
Important Take-Home-Message

The rewrite rule where the N-bar symbol occurs on both sides is the core part of the set of rewrite rules which allows for **infinite recursive application**:

$$\overline{\text{N}} \rightarrow \text{A}\ \overline{\text{N}}$$

Note: This rule is of the type $X \rightarrow YZ$ with $X = Z$, and is hence a *recursive context-free* (or higher level) rule. Remember from the lecture on the Chomsky Hierarchy that rules of the type $X \rightarrow xY$ are regular/finite state. There is a common misunderstanding that regular/finite state grammars are non-recursive. This is false, regular/finite state grammars *can be recursive*, namely if $X = Y$.

Noun Phrase Examples



Rewrite Notation

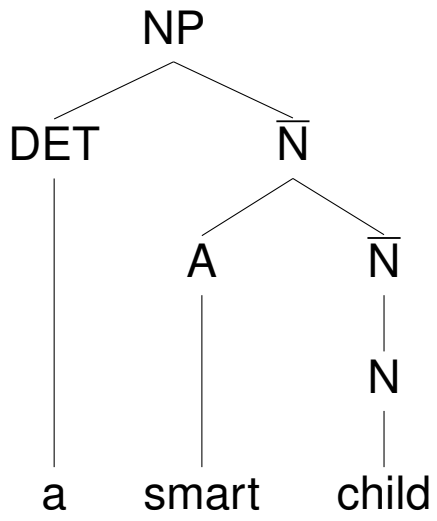
NP
DET $\bar{\mathbf{N}}$
DET **N**

---

a N
a child

Note: Compared to the earlier notation without bars we have an increase in so-called *unary branches*, since we always need to rewrite the element with a bar into an element without the bar.

Noun Phrase Examples



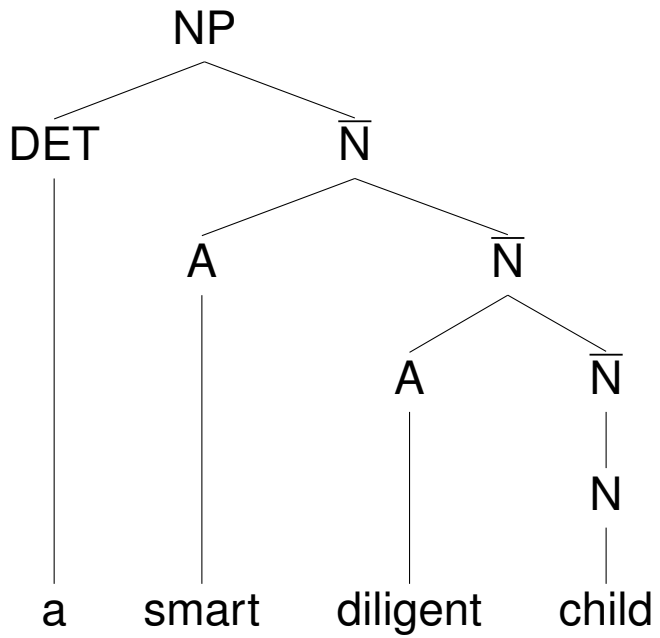
Rewrite Notation

NP
DET N̄
DET A N̄
DET A N

---

a A N
a smart N
a smart child

Noun Phrase Examples



Rewrite Notation

NP
DET N̄
DET A N̄
DET A A N̄
DET A A N

---

a A A N
a smart A N
a smart diligent N
a smart diligent child

Other Adjuncts (PPs and Relative Clauses)

"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 N in an analogous way to adjectives [...]"

5. $\overline{\text{N}} \rightarrow \overline{\text{N}}$ PP (e.g. the woman from Stuttgart)
6. $\overline{\text{N}} \rightarrow$ N PP (e.g. father of Peter)
7. $\overline{\text{N}} \rightarrow \overline{\text{N}}$ REL (e.g. the woman who ...)

Müller (2019). Grammatical theory, p. 66.

Note: Rule 5 is a special rule for so-called *relational nouns* (e.g. *father (of)*, *son (of)*, *picture (of)*). Here, the PP is considered a direct complement of the noun (i.e. a possessive construction would be incomplete without it).

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The Prepositional Phrase

Prepositional Phrases

"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:"

$$PP \rightarrow P\ NP$$

Müller (2019). Grammatical theory, p. 71.

However, we also need to cover the following examples:

(7) [PP [**NP one step**] [PP before [NP the abyss]]]

(8) [PP [**A shortly**] [PP after [NP the take.off]]]

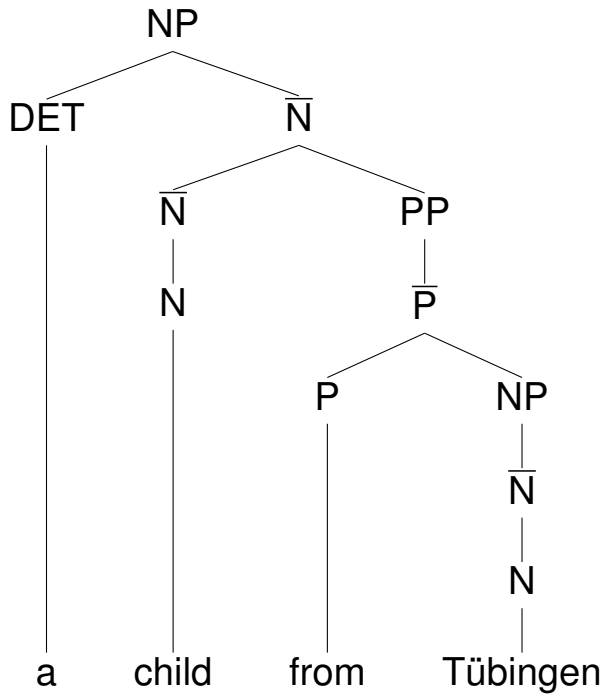
Prepositional Phrases

In order to cover such examples including an indication of measurement (e.g. *shortly*, *one step*) we can choose the following set of X-bar rules:

8. PP $\rightarrow$ NP $\overline{\text{P}}$
9. PP $\rightarrow$ AP $\overline{\text{P}}$
10. PP $\rightarrow$ $\overline{\text{P}}$
11. $\overline{\text{P}}$ $\rightarrow$ P NP

Müller (2019). Grammatical theory, p. 72.

Prepositional Phrase Example



Rewrite Notation

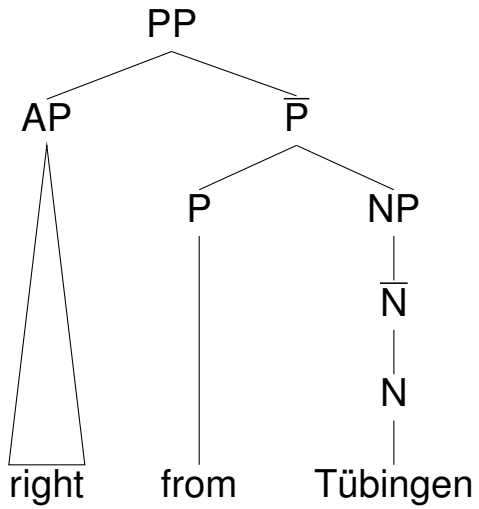
NP
DET N̄
DET N̄ PP
DET N P̄
DET N P NP
DET N P N̄
DET N P N

---

a N P N
a child P N
etc.

Note: There is an inflation of non-terminal rewritings due to the fact that X-bar elements have to be rewritten into elements without the bar before being rewritten into the terminals.

Prepositional Phrase Example (with Adjective)



Rewrite Notation

PP
AP $\overline{P}$
AP P NP
AP P $\overline{N}$
AP P N

---

right P N
right from N
right from Tübingen

Note: We haven't defined the structure of adjective phrases (AP) according to X-bar rules yet. Hence, the AP is directly connected to the terminal word *right* by a triangle, which is a placeholder for the actual branching structure.

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The Adjective Phrase

Adjective Phrases

Müller (2019), p. 74 gives the following examples of adjective phrases that need to be covered by corresponding X-bar rules:

(9) proud

(10) very proud

(11) proud of his son

(12) very proud of his son

Adjective Phrases

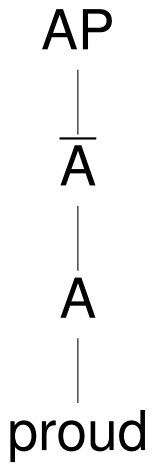
Therefore, he proposes the following rules:

12. AP → $\overline{\text{A}}$
13. AP → AdvP[6] $\overline{\text{A}}$
14. $\overline{\text{A}}$ → A PP
15. $\overline{\text{A}}$ → A

Müller (2019). Grammatical theory, p. 74.

[6] We do not further define the internal structure of an adverb phrase here. We just assume that this can be directly rewritten with unary rewrites into a terminal string, e.g. AdvP → $\overline{\text{Adv}}$ → Adv → very.

Adjective Phrase Examples

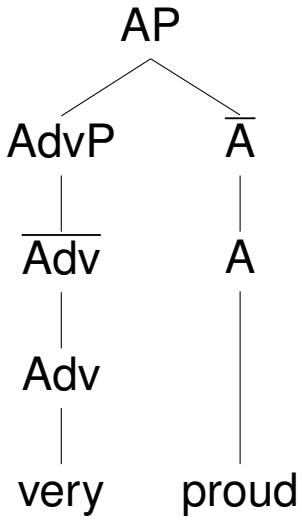


Rewrite Notation

AP
$\overline{A}$
A

---

proud



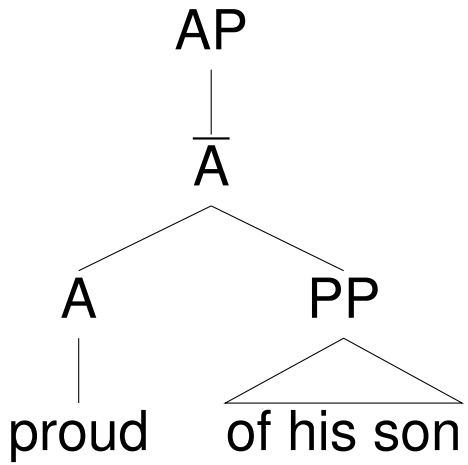
Rewrite Notation

AP
AdvP $\overline{A}$
AdvP A

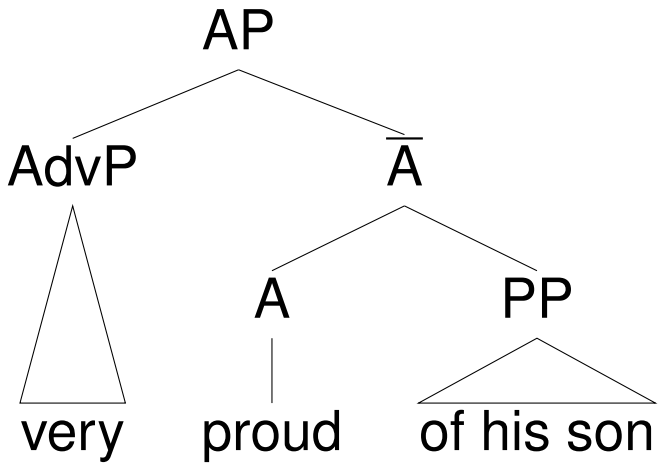
---

very A
very proud

Adjective Phrase Examples

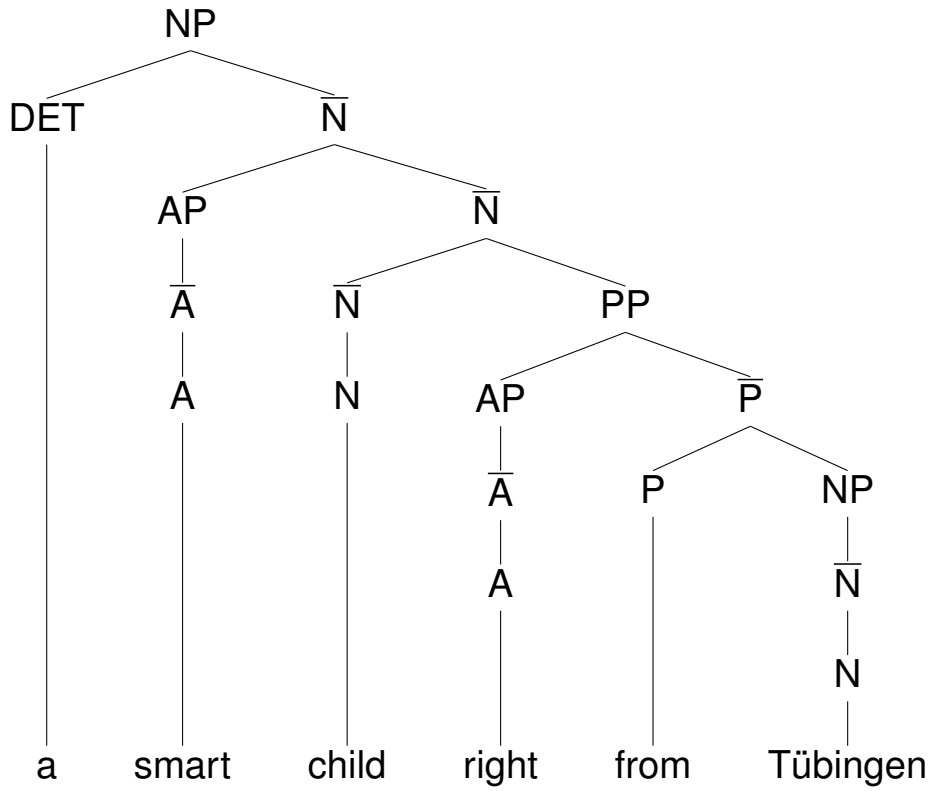


Rewrite Notation
AP
Ā
A PP
proud PP
etc.



Rewrite Notation
AP
AdvP Ā
AdvP A PP
very A PP
etc.

Full Example



Rewrite Rules

1. NP → DET $\bar{N}$
2. NP → $\bar{N}$
3. $\bar{N}$ → AP $\bar{N}$
4. $\bar{N}$ → N
5. $\bar{N}$ → $\bar{N}$ PP
6. $\bar{N}$ → N PP
7. $\bar{N}$ → $\bar{N}$ REL
8. PP → NP $\bar{P}$
9. PP → AP $\bar{P}$
10. PP → $\bar{P}$
11. $\bar{P}$ → P NP
12. AP → $\bar{A}$
13. AP → AdvP $\bar{A}$
14. $\bar{A}$ → A PP
15. $\bar{A}$ → A

Notes: The rule number two was modified (A → AP). Rule number seven is not included here as it was replaced by other rules of the X-bar notation.

Important Take-Home-Message

Introducing **two bar-levels** (e.g. NP and N-bar) allows us to apply *recursiveness* where necessary, but also avoid it were it would lead to *ungrammatical* structures.

- the smart, diligent, quite, [...] child ($\overline{N} \rightarrow AP\ \overline{N}$)
- *the smart the child, the dog, the cat ()
- the child from Tübingen, on the Herrlesberg, in the blue house [...] ($\overline{N} \rightarrow \overline{N}\ PP$)
- *the child from on by Tübingen

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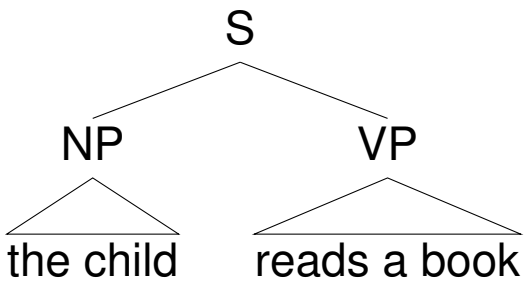
The Verb Phrase

The Sentence Level

In the early X-bar theoretic work by Chomsky in 1970 the highest level is represented by the *S* symbol as before in the phrase structure accounts of the 1950s and 60s. This symbol is later replaced by other symbols (see lecture on Government and Binding). We thus have the rule:

16. S $\rightarrow$ NP VP

Chomsky (1970), p. 211.

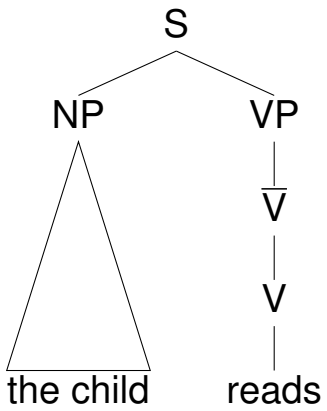


The Verb Phrase: Intransitive

We might allow the VP to be rewritten simply into a *V at the one-bar level*, and then into a head. This is the case of an *intransitive* usage. We would thus have the rules:

17. $VP \rightarrow \overline{V}$
18. $\overline{V} \rightarrow V$

See Carnie (2013), p. 173 rule 48.

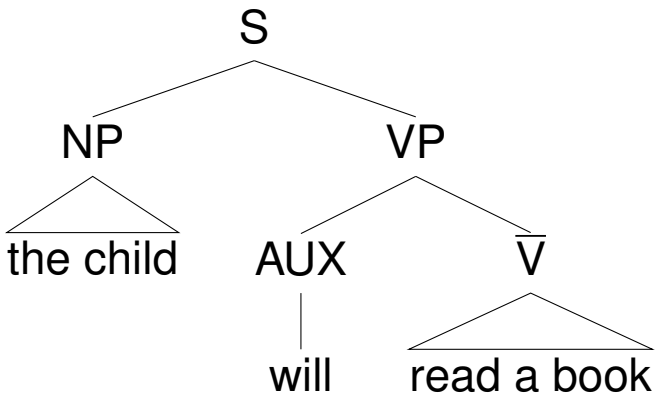


The Verb Phrase: Auxiliary Verb

Within the VP, we might allow an auxiliary verb to occur (e.g. in English). We would thus have the rule:

19. $VP \rightarrow AUX\ \overline{V}$

Adopted from Chomsky (1970), p. 211.

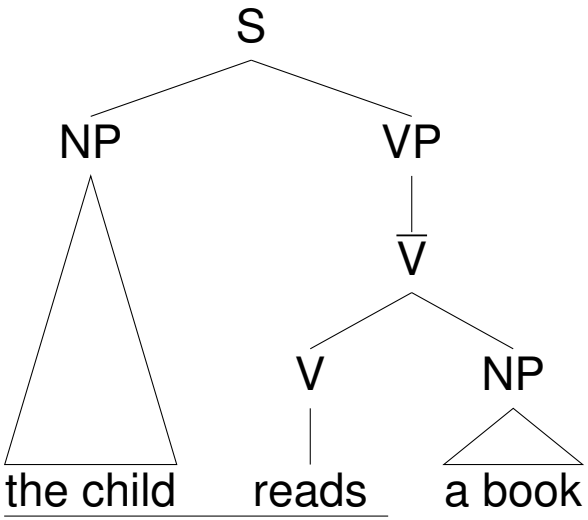


The Verb Phrase: Transitives

We further assume that $\overline{V}$ can be rewritten into a V-head with one NP, i.e. in the *transitive* usage:[7]

20. $\overline{V} \rightarrow V\ NP$

See Carnie (2013), p. 173 rule 50.



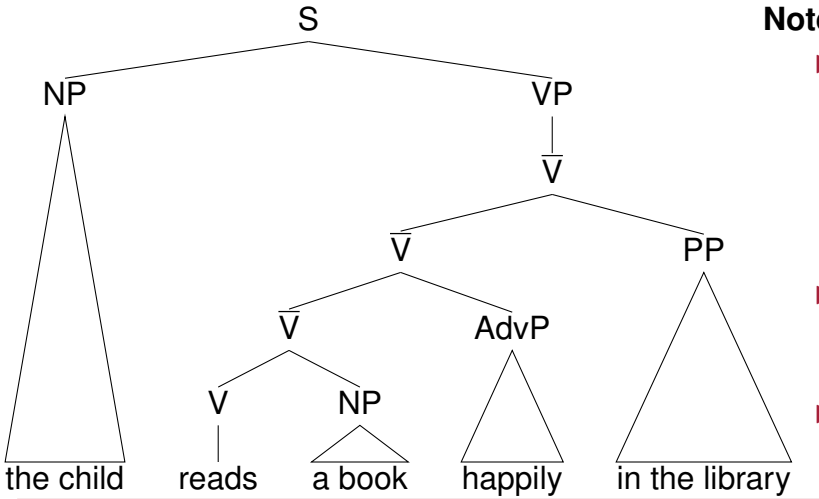
[7] How particular verbs select for one, two, or even three arguments is not accounted for in this simple framework. Also, Carnie (2013, p. 412) discusses the issue of ditransitives, and that this is not easily solved if we assume binary branching.

The Verb Phrase: Adjuncts

Finally, adjuncts can be added to the verb phrase *recursively* (at the level of $\overline{V}$. These are mainly going to be adverbial (AdvP) or prepositional phrases (PP).

21. $\overline{V} \rightarrow \overline{V}$ AdvP (or AdvP $\overline{V}$)
22. $\overline{V} \rightarrow \overline{V}$ PP

See Carnie (2013), p. 173 rule 49.



Notes:

- Arguably, recursiveness is justified in these rules since sentences of the type *the child reads a book happily, carefully, silently [...] in the library, on the top floor, at the desk to the right [...]* are grammatical (if maybe a bit odd).
- The order of AdvP and PP could be inverted according to the rules: ?*the child reads a book in the library happily*.
- The AdvP could also precede the verb: *the child happily reads a book in the library*.

Notation Glossary

A: adjective
AP: adjective phrase
Adv: adverb
AdvP: adverbial phrase
COMPL: complementizer (i.e. *that*)
DET: determiner
N: noun
NP: noun phrase
P: preposition
PP: prepositional phrase
PRON: pronoun
REL: relative clause
V: verb
VP: verb phrase

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Section 4: $\overline{X}$ Theory

A Shift in Focus

> *It would, for example, be extremely interesting to know whether it is in principle possible to construct a* ***phrase structure grammar for English*** *(even though there is good motivation of other kinds for not doing so). Before we can hope to answer this, it will be necessary to discover the structural properties that characterize the languages that can be enumerated by grammars of these various types.*

Chomsky (1965). On certain formal properties of grammars, p. 139.

> *We should be concerned to* ***abstract*** *from successful grammars and successful theories those* ***more general properties*** *that account for their success, and to develop [universal grammar] as a theory of these abstract properties, which might be realized in a variety of different ways.*

Chomsky (1981). Lectures on government and binding, p.2.

$\overline{X}$ rules

Grammarians (mostly working with English) realized that different phrase structure rules have structural similarities and can hence be capture in more abstract form by using **X as a placeholder** for other non-terminal symbols.

See also discussion in Müller (2019), p. 75.

$$\overline{\overline{X}} \equiv XP \rightarrow NP, VP, AP, PP, \text{etc.}$$

$$\overline{X} \rightarrow \overline{N}, \overline{V}, \overline{A}, \overline{P}, \text{etc.}$$

$$X \rightarrow N, V, A, P, \text{etc.}$$

Examples of $\overline{X}$ rules

Rewrite Rules

1. **NP** → **DET** $\overline{\textbf{N}}$
2. NP → $\overline{\text{N}}$
3. $\overline{\text{N}}$ → AP $\overline{\text{N}}$
4. $\overline{\text{N}}$ → N
5. $\overline{\text{N}}$ → $\overline{\text{N}}$ PP
6. $\overline{\text{N}}$ → N PP
7. $\overline{\text{N}}$ → $\overline{\text{N}}$ REL
8. **PP** → **NP** $\overline{\textbf{P}}$
9. **PP** → **AP** $\overline{\textbf{P}}$
10. PP → $\overline{\text{P}}$
11. $\overline{\text{P}}$ → P NP
12. AP → $\overline{\text{A}}$
13. **AP** → **AdvP** $\overline{\textbf{A}}$
14. $\overline{\text{A}}$ → A PP
15. $\overline{\text{A}}$ → A

Bar-notation:

1. $\overline{\overline{\text{N}}} \rightarrow \overline{\overline{\text{DET}}}^{1}\ \overline{\text{N}}$
8. $\overline{\overline{\text{P}}} \rightarrow \overline{\overline{\text{N}}}\ \overline{\text{P}}$
9. $\overline{\overline{\text{P}}} \rightarrow \overline{\overline{\text{A}}}\ \overline{\text{P}}$
13. $\overline{\overline{\text{A}}} \rightarrow \overline{\overline{\text{Adv}}}\ \overline{\text{A}}$

X-bar rule:

$\overline{\overline{\textbf{X}}} \rightarrow \overline{\overline{\textbf{specifier}}}\ \overline{\textbf{X}}$

[1] Note that this means we need two more re-write rules, and hence have several unary branches for determiners: e.g. DP ($\overline{\overline{DET}}$) → $\overline{DET}$ → DET → the.

Examples of $\overline{X}$ rules

Rewrite Rules

1. NP → DET $\overline{N}$
2. NP → $\overline{N}$
3. **$\overline{N}$ → AP $\overline{N}$**
4. $\overline{N}$ → N
5. **$\overline{N}$ → $\overline{N}$ PP**
6. $\overline{N}$ → N PP
7. **$\overline{N}$ → $\overline{N}$ REL**
8. PP → NP $\overline{P}$
9. PP → AP $\overline{P}$
10. PP → $\overline{P}$
11. $\overline{P}$ → P NP
12. AP → $\overline{A}$
13. AP → AdvP $\overline{A}$
14. $\overline{A}$ → A PP
15. $\overline{A}$ → A

Bar-notation:

3. $\overline{N} \rightarrow \overline{A}\ \overline{N}$
5. $\overline{N} \rightarrow \overline{N}\ \overline{P}$
7. $\overline{N} \rightarrow \overline{N}\ \overline{REL}$

X-bar rule:

$\overline{X} \rightarrow \overline{\text{adjunct}}\ \overline{X}$

or

$\overline{X} \rightarrow \overline{X}\ \overline{\text{adjunct}}$

Examples of $\overline{X}$ rules

Rewrite Rules

[...]
6. $\overline{\mathbf{N}} \rightarrow$ **N PP**
[...]
16. S $\rightarrow$ NP VP
17. VP $\rightarrow \overline{V}$
18. $\overline{V} \rightarrow$ V
19. VP $\rightarrow$ AUX $\overline{V}$
20. $\overline{\mathbf{V}} \rightarrow$ **V NP**
21. $\overline{V} \rightarrow \overline{V}$ AdvP
22. $\overline{V} \rightarrow \overline{V}$ PP
etc.

Bar-notation:

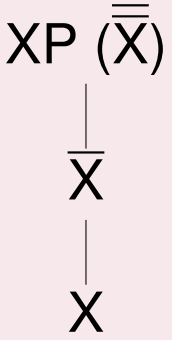
6. $\overline{N} \rightarrow$ N $\overline{\overline{P}}$
20. $\overline{V} \rightarrow$ V $\overline{\overline{N}}$

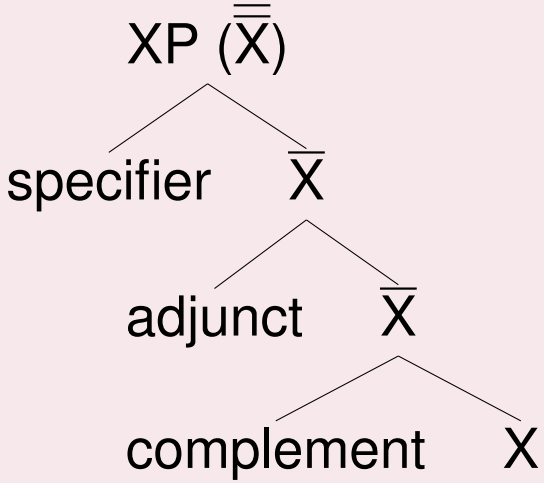
X-bar rule:

$\overline{\mathbf{X}} \rightarrow$ **X** $\overline{\overline{\textbf{complement}}}$

Maximal and Minimal $\overline{X}$ phrases

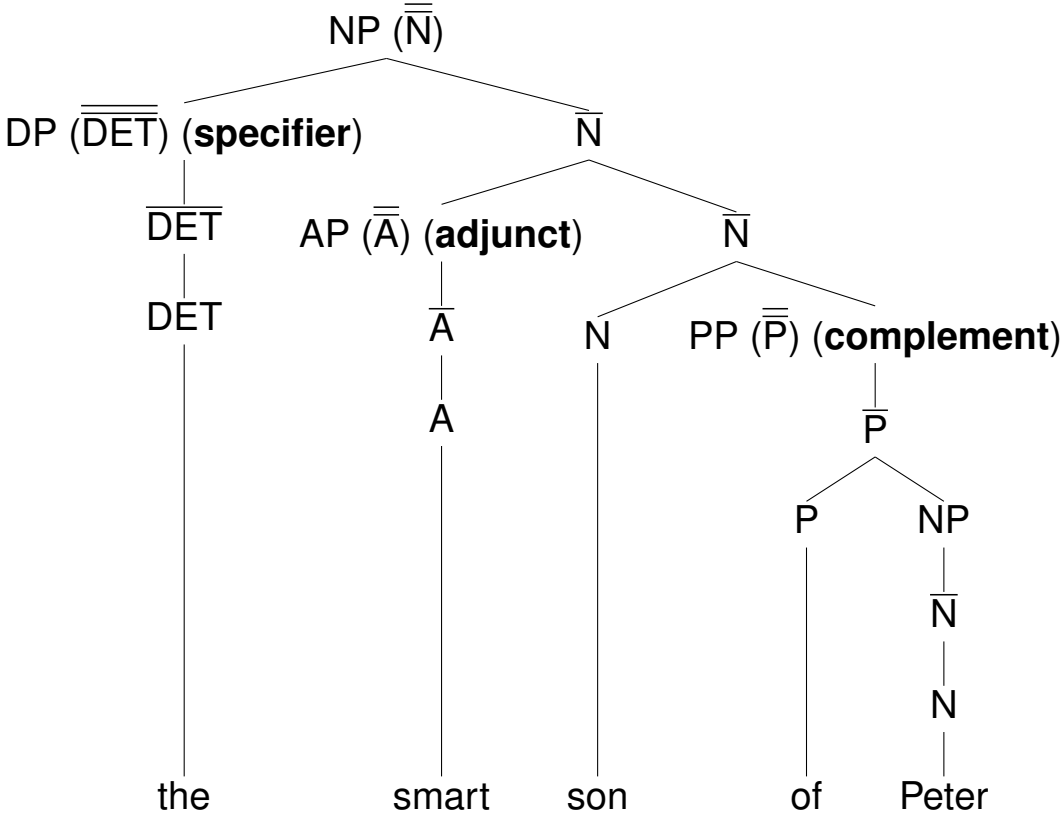
Given all the generalized $\overline{X}$ rules above we get to the **minimal** and **maximal phrase structure** possible within $\overline{X}$ theory:





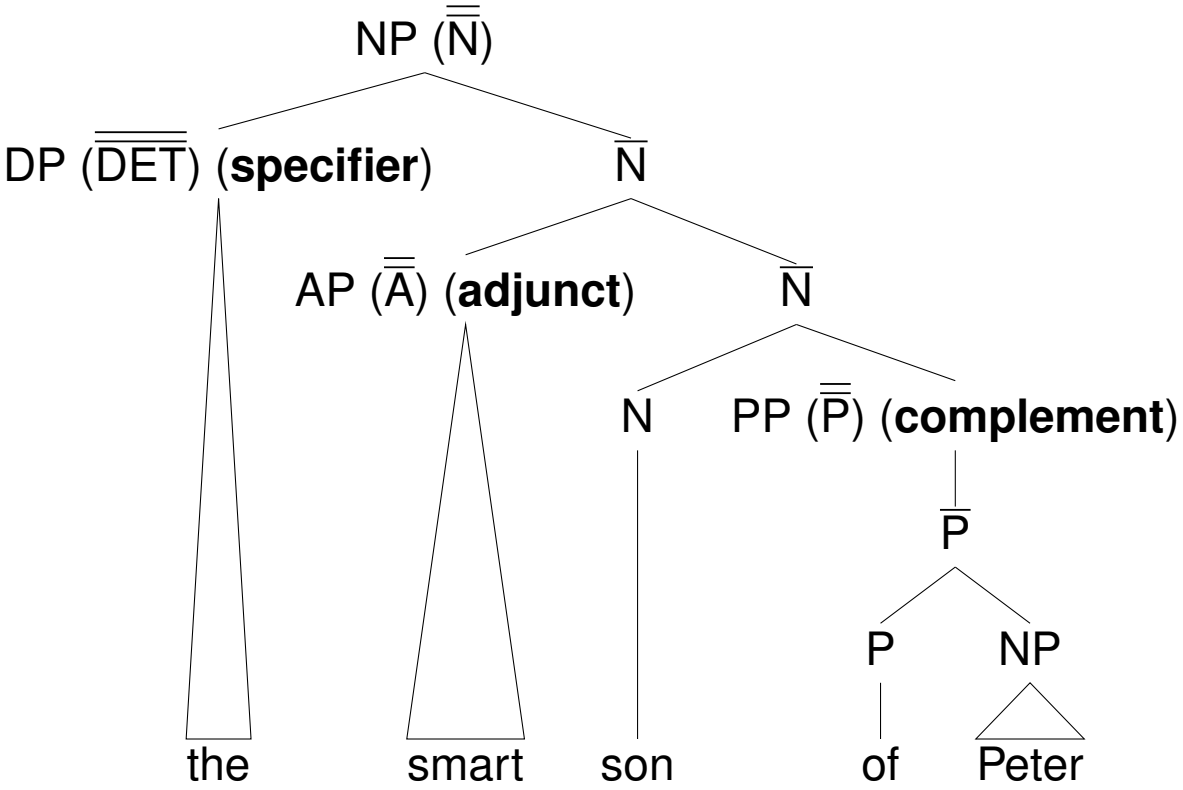
Müller (2019). Grammatical theory, p. 76.

Example of Maximal $\overline{X}$-Phrase



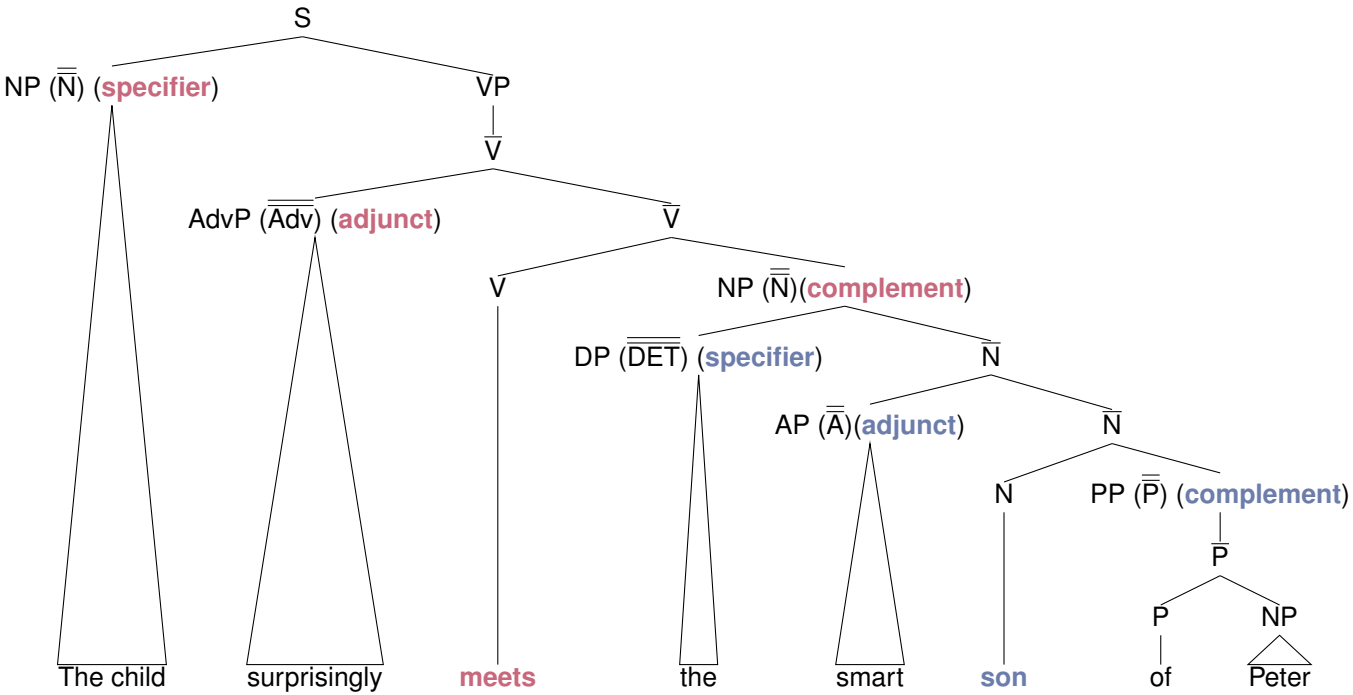
Note: *son* is here a *relational noun*. With the example above (the smart child from Tübingen) the analysis is slightly different. Namely, the PP *from Tübingen* would not be considered a complement, but an adjunct.

Example of Maximal $\overline{X}$-Phrase (with triangles)



Note: *son* is here a *relational noun*. With the example above (the smart child from Tübingen) the analysis is slightly different. Namely, the PP *from Tübingen* would not be considered a complement, but an adjunct.

Example of Maximal $\overline{X}$-Phrases



Notice how the heads of these phrases (i.e. **meets** and **son**) can both have **specifiers**, **adjuncts**, and **complements**. So both full sentences and NPs can follow the same X-bar template. This only works here with a relational noun (*son of*) though. With other nouns (e.g. *book of*) we would consider the PP an adjunct.

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Section 5: Pros and Cons of $\overline{X}$ theory

Pros (Advantages)

- Explicitely models the productiveness of natural language by recursively applying rules (though note that recursive application is also possible in classical PSGs)
- Abstracts away from ideosyncrasies of particular phrase types and formulates more general rules (X-bar rules)
- While we haven't discussed morphological features in this lecture, these can be implemented (similar to PSG)

Cons (Disadvantages)

- The bar-notation leads to an inflation of unary branches, and, more generally, makes the analyses of even relatively simple sentences quite daunting.
- Justifying the higher level $\overline{X}$ rules based on empirical data (i.e. grammatical and ungrammatical sentences) becomes increasingly difficult and controversial.

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Section 6: Basic Concepts in $\overline{X}$ theory

Basic Concepts in $\overline{X}$ theory

- Constituency ✓
- POS ✓
- Heads ✓
- Valency ✓[8]
- Grammatical Functions ✓[9]

[8] Similar as for PSGs, valency is to some extent an issue when formulating rewrite rules.

[9] Grammatical functions play an indirect role here, since (at least in English) subjects of verbs are supposed to be in specifier position, and objects in the complement position.

Section 7: References

References

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Thank You.

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