

# Ling 566

## Oct 17, 2023

How the Grammar Works

# Overview

- What we're trying to do
- The pieces of our grammar
- Two extended examples
- Reflection on what we've done, what we still have to do

# What We're Trying To Do

- Objectives
  - Develop a theory of knowledge of language
  - Represent linguistic information explicitly enough to distinguish well-formed from ill-formed expressions
  - Be parsimonious, capturing linguistically significant generalizations.
- Why Formalize?
  - To formulate testable predictions
  - To check for consistency
  - To make it possible to get a computer to do it for us

# Why does this matter to NLP?

- Understand how language works => better positioned to build technology that works with language
- For some applications, grammar engineering is a valuable component directly
- Grammar engineering can also support extremely detailed annotation

# How We Construct Sentences

- The Components of Our Grammar
  - Grammar rules
  - Lexical entries
  - Principles
  - Type hierarchy (very preliminary, so far)
  - Initial symbol (S, for now)
- We combine constraints from these components.
  - Q: What says we have to combine them?

# The Definition of Well-Formed Structures

(39) **Well-Formed Tree Structure:**

$\Phi$  is a Well-Formed Tree Structure according to  $G$  if and only if:

1.  $\Phi$  is a tree structure,
2. the label of  $\Phi$ 's root node satisfies  $S$ ,<sup>17</sup> and
3. each local subtree within  $\Phi$  is either phrasally licensed or lexically licensed.

(40) **Lexical Licensing:**

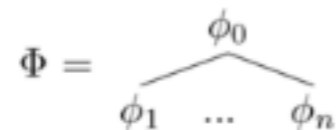
A word structure of the form:



is licensed if and only if  $G$  contains a lexical entry  $\langle d_1, d_2 \rangle$ , where  $\omega$  satisfies  $d_1$  and  $\phi$  satisfies  $d_2$ .

(41) **Phrasal Licensing:**

A grammar rule  $\rho = d_0 \rightarrow d_1 \dots d_n$  licenses a local subtree:



if and only if:

1. for each  $i, 0 \leq i \leq n$ ,  $\phi_i$  is of<sup>18</sup> the type *expression*,
2. there is some assignment function  $g$  under which the sequence  $\langle \phi_0, \phi_1, \dots, \phi_n \rangle$  satisfies the description sequence  $\langle d_0, d_1, \dots, d_n \rangle$ ,<sup>19</sup>
3.  $\Phi$  satisfies the Semantic Compositionality Principle, and
4. if  $\rho$  is a headed rule, then  $\Phi$  satisfies the Head Feature Principle, the Valence Principle and the Semantic Inheritance Principle, with respect to  $\rho$ .

# An Example

*A cat slept.*

- Can we build this with our tools?
- Given the constraints our grammar puts on well-formed sentences, is this one?

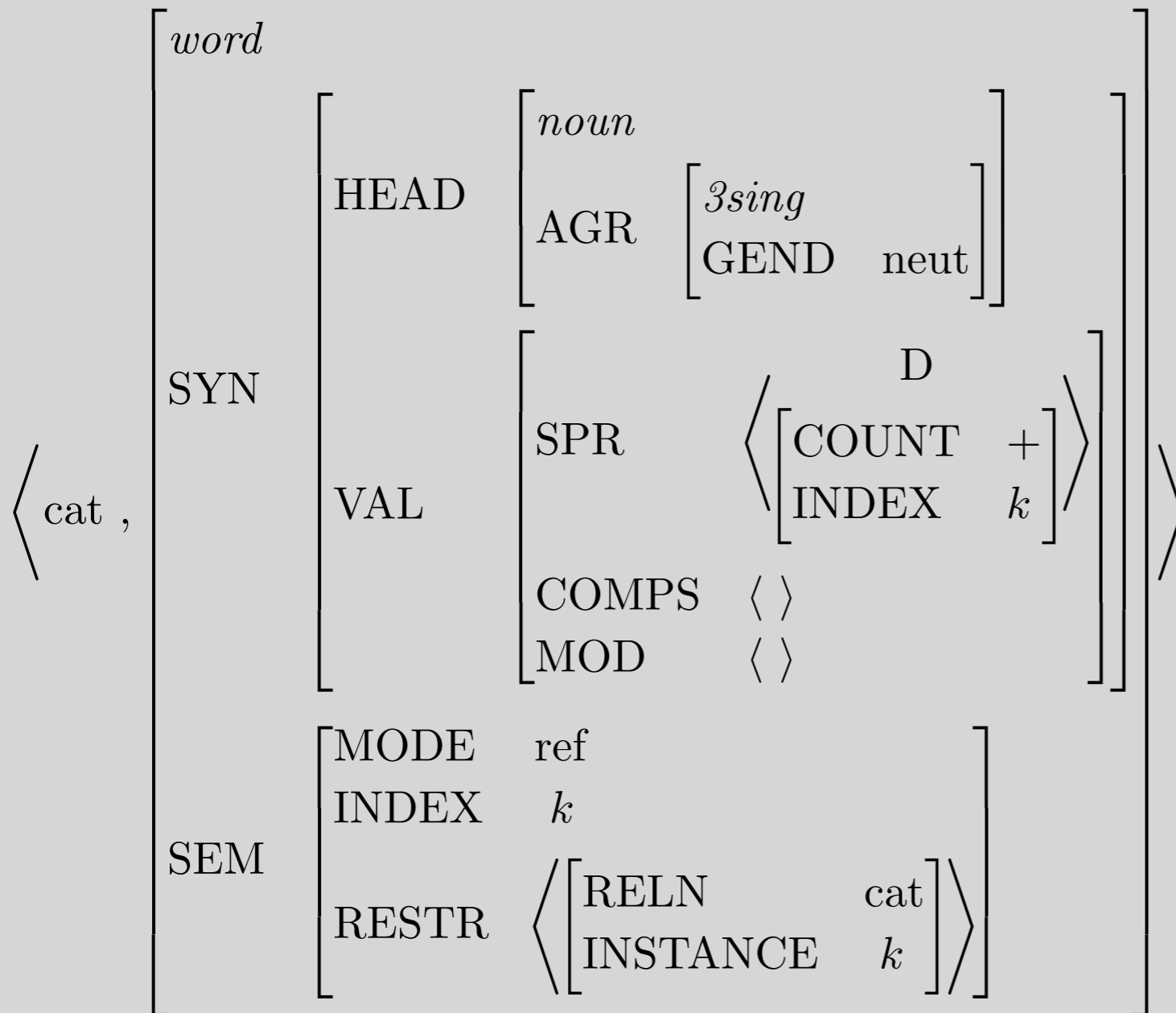
# Lexical Entry for *a*

$\langle a, \rangle$	$\left[ \begin{array}{l} \text{word} \\ \\ \text{SYN} \\ \\ \text{SEM} \end{array} \right.$	$\left[ \begin{array}{l} \text{HEAD} \\ \\ \text{VAL} \\ \\ \text{MODE} \\ \text{INDEX} \\ \text{RESTR} \end{array} \right.$	$\left[ \begin{array}{l} \text{det} \\ \text{AGR} \\ \text{COUNT} \\ \\ \text{COMPS} \\ \text{SPR} \\ \text{MOD} \\ \\ \text{none} \\ j \\ \left\langle \left[ \begin{array}{l} \text{RELN} \\ \text{BV} \end{array} \right] \right\rangle \end{array} \right.$	$\left[ \begin{array}{l} \\ \\ 3sing \\ + \\ \\ \langle \rangle \\ \langle \rangle \\ \langle \rangle \\ \\ \\ a \\ j \end{array} \right.$	$\rangle$
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- Is this a fully specified (resolved) description?
- What features are unspecified?
- How many word structures can this entry license?

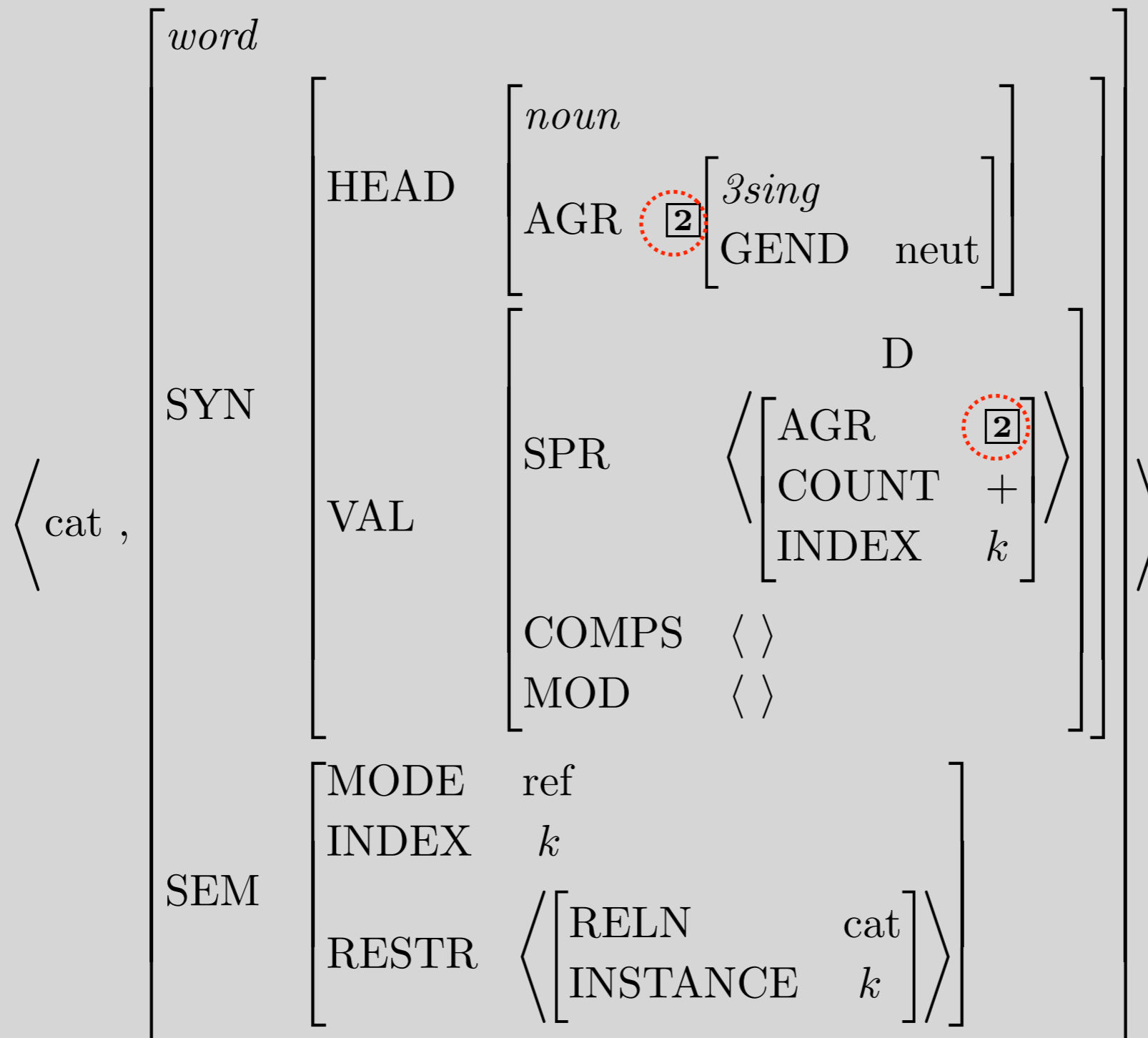


# Lexical Entry for *cat*

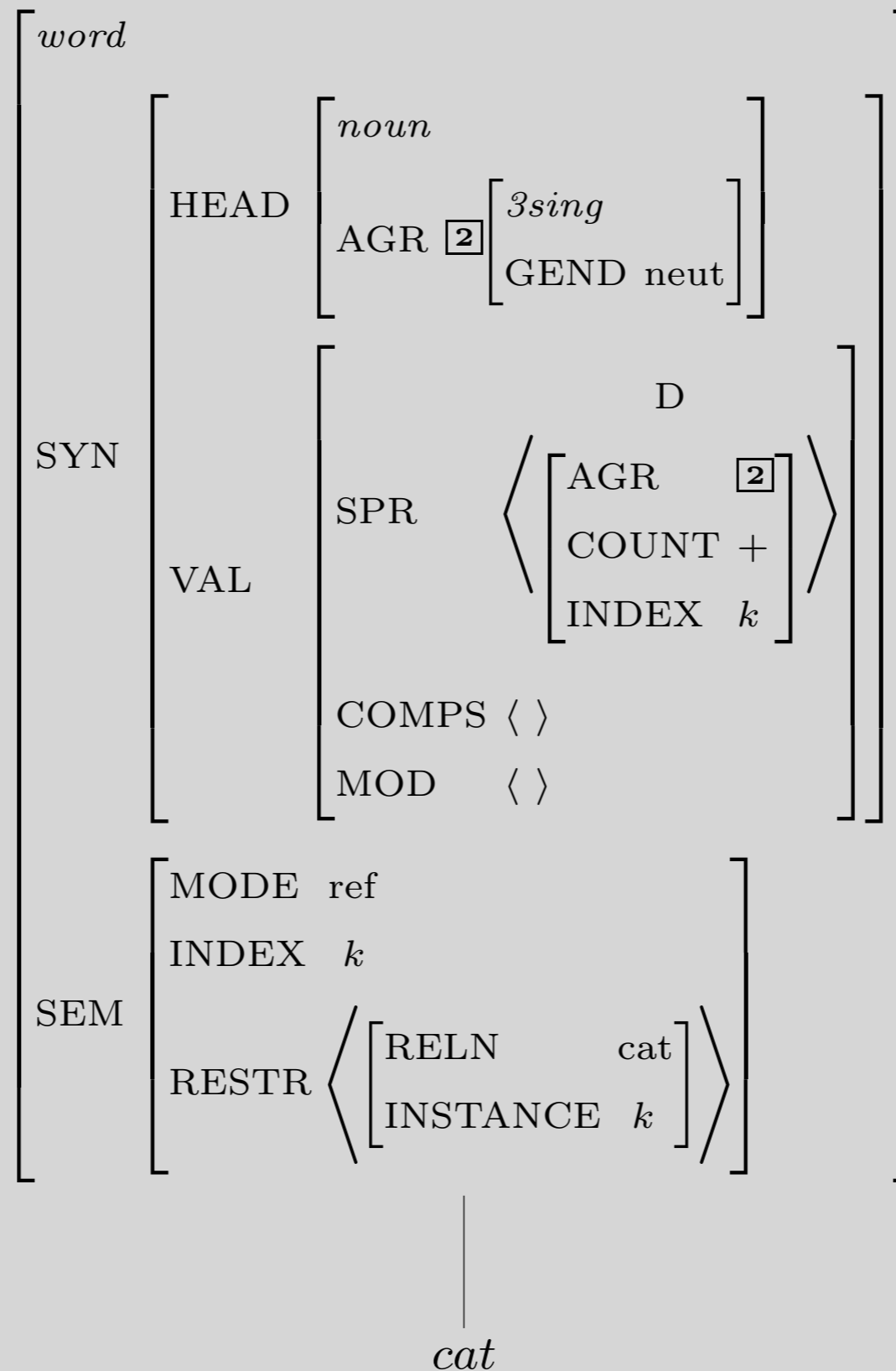


- Which feature paths are abbreviated?
- Is this a fully specified description?
- What features are unspecified?
- How many word structures can this entry license?

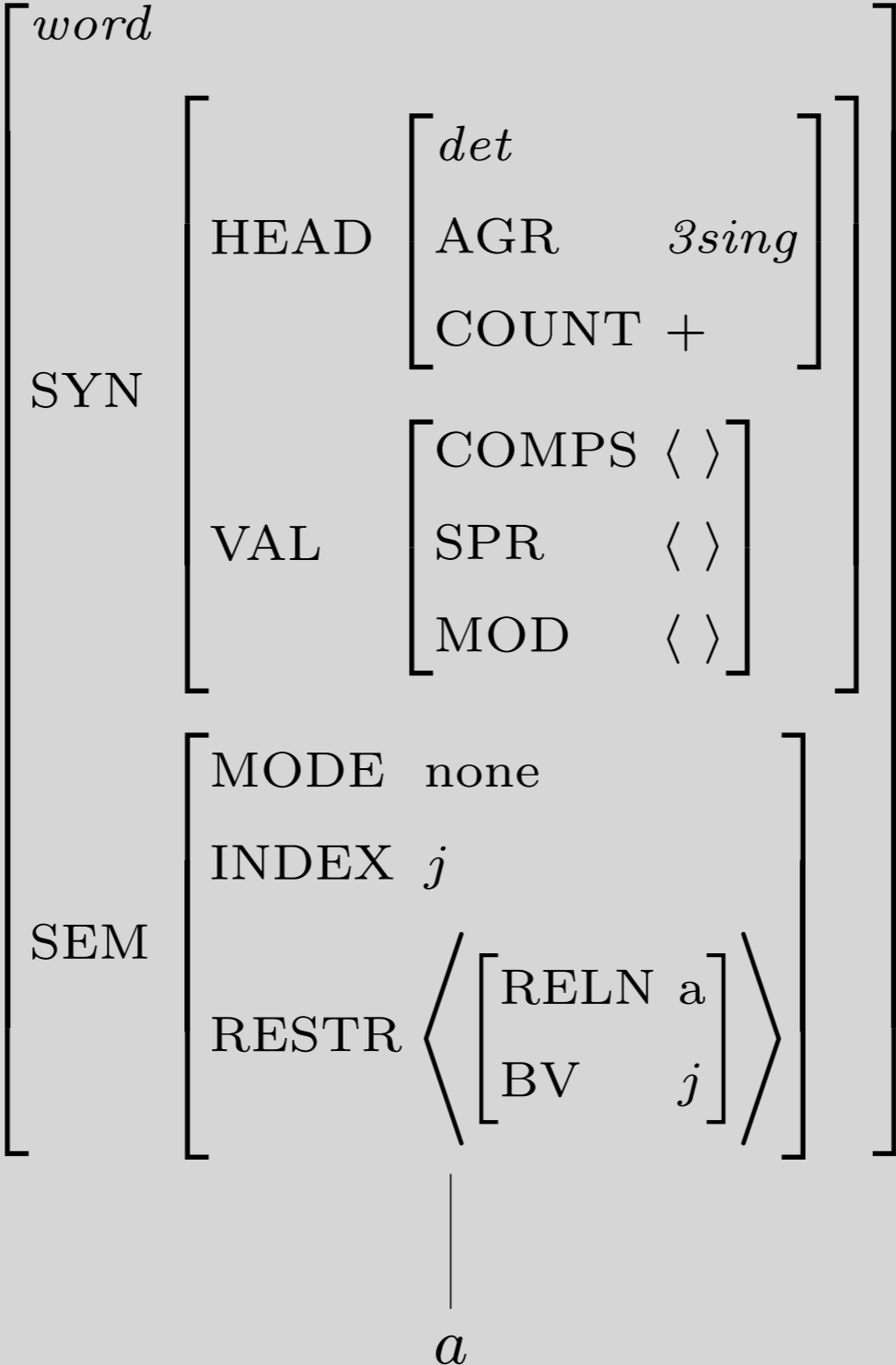
# Effect of Principles: the SHAC



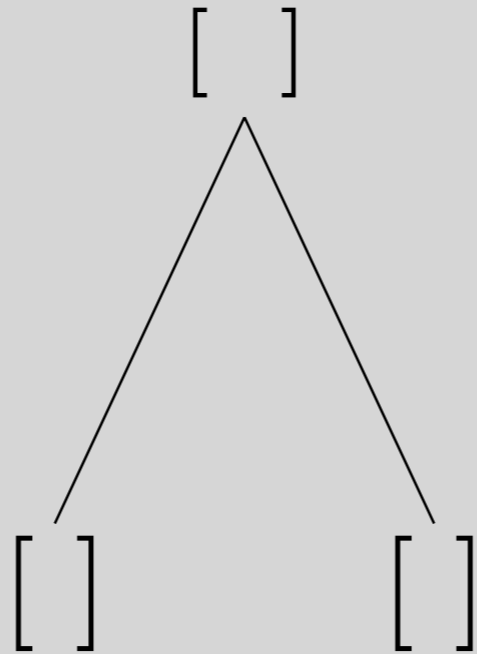
# Description of Word Structures for *cat*



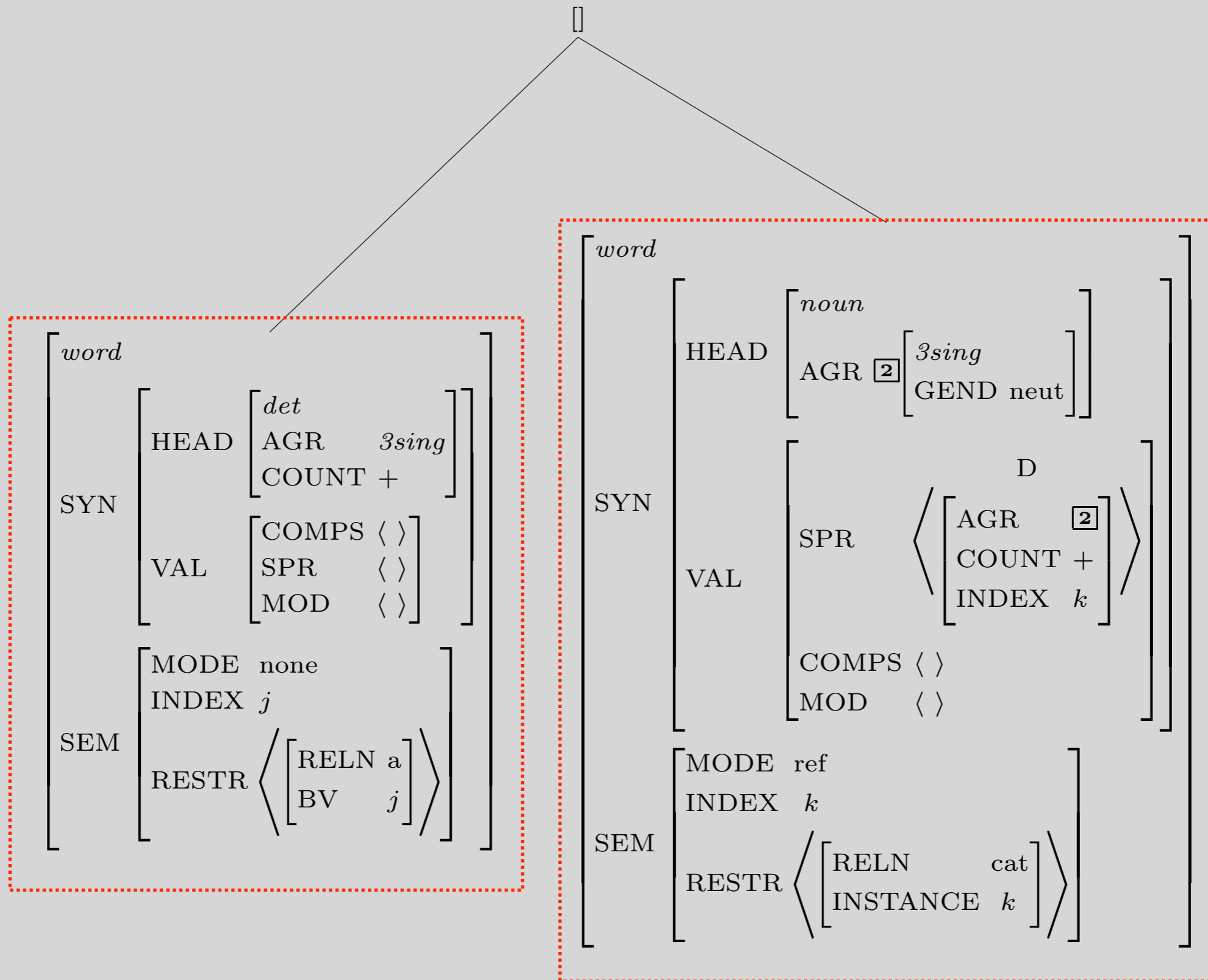
# Description of Word Structures for *a*



# Building a Phrase



# Constraints Contributed by Daughter Subtrees



# Constraints Contributed by the Grammar Rule

(56) Head-Specifier Rule  

$$\left[ \begin{array}{l} \textit{phrase} \\ \text{SYN} \left[ \text{VAL} \left[ \text{SPR} \langle \rangle \right] \right] \end{array} \right] \rightarrow \boxed{7} \mathbf{H} \left[ \text{SYN} \left[ \text{VAL} \left[ \begin{array}{l} \text{SPR} \langle \boxed{7} \rangle \\ \text{COMPS} \langle \rangle \end{array} \right] \right] \right]$$
*A phrase can consist of a (lexical or phrasal) head preceded by its specifier.*

$$\left[ \begin{array}{l} \textit{phrase} \\ \text{SYN} \left[ \text{VAL} \left[ \text{SPR} \langle \rangle \right] \right] \end{array} \right]$$

$$\left[ \begin{array}{l} \textit{word} \\ \text{SYN} \left[ \begin{array}{l} \text{HEAD} \left[ \begin{array}{l} \textit{det} \\ \text{AGR} \left[ \begin{array}{l} 3\textit{sing} \\ \text{GEND neut} \end{array} \right] \\ \text{COUNT} + \end{array} \right] \\ \text{VAL} \left[ \begin{array}{l} \text{COMPS} \langle \rangle \\ \text{SPR} \langle \rangle \\ \text{MOD} \langle \rangle \end{array} \right] \end{array} \right] \\ \text{SEM} \left[ \begin{array}{l} \text{MODE none} \\ \text{INDEX } k \\ \text{RESTR} \left\langle \left[ \begin{array}{l} \text{RELN } a \\ \text{BV } k \end{array} \right] \right\rangle \end{array} \right] \end{array} \right]$$

$$\left[ \begin{array}{l} \textit{word} \\ \text{SYN} \left[ \begin{array}{l} \text{HEAD} \left[ \begin{array}{l} \textit{noun} \\ \text{AGR} \left[ \begin{array}{l} 3\textit{sing} \\ \text{GEND neut} \end{array} \right] \end{array} \right] \\ \text{VAL} \left[ \begin{array}{l} \text{SPR} \left\langle \left[ \begin{array}{l} \boxed{7} \text{D} \\ \text{COUNT} + \\ \text{INDEX } k \end{array} \right] \right\rangle \\ \text{COMPS} \langle \rangle \\ \text{MOD} \langle \rangle \end{array} \right] \\ \text{SEM} \left[ \begin{array}{l} \text{MODE ref} \\ \text{INDEX } k \\ \text{RESTR} \left\langle \left[ \begin{array}{l} \text{RELN } \textit{cat} \\ \text{INSTANCE } k \end{array} \right] \right\rangle \end{array} \right] \end{array} \right]$$

# A Constraint Involving the SHAC

(62) Specifier-Head Agreement Constraint (SHAC)  
Verbs and common nouns must be specified as:

$$\left[ \text{SYN} \left[ \text{HEAD} \left[ \text{AGR} \boxed{7} \right] \right] \right]$$

$$\left[ \text{VAL} \left[ \text{SPR} \langle \left[ \text{AGR} \boxed{7} \right] \rangle \right] \right]$$

$$\left[ \textit{phrase} \right]$$

$$\left[ \text{SYN} \left[ \text{VAL} \left[ \text{SPR} \langle \rangle \right] \right] \right]$$

$$\left[ \textit{word} \right]$$

$$\left[ \text{SYN} \left[ \text{HEAD} \left[ \text{det} \right] \right] \right]$$

$$\left[ \text{AGR} \left[ \begin{array}{l} 3sing \\ \text{GEND neut} \end{array} \right] \right]$$

$$\left[ \text{COUNT} + \right]$$

$$\left[ \text{VAL} \left[ \text{COMPS} \langle \rangle \right] \right]$$

$$\left[ \text{SPR} \langle \rangle \right]$$

$$\left[ \text{MOD} \langle \rangle \right]$$

$$\left[ \text{SEM} \left[ \text{MODE} \text{ none} \right] \right]$$

$$\left[ \text{INDEX} k \right]$$

$$\left[ \text{RESTR} \left\langle \left[ \text{RELN} a \right] \right\rangle \right]$$

$$\left[ \text{BV} k \right]$$

$$\left[ \textit{word} \right]$$

$$\left[ \text{HEAD} \left[ \textit{noun} \right] \right]$$

$$\left[ \text{AGR} \left[ \begin{array}{l} 3sing \\ \text{GEND neut} \end{array} \right] \right]$$

$$\left[ \text{SYN} \left[ \text{VAL} \left[ \text{SPR} \left\langle \left[ \text{COUNT} + \right] \right\rangle \right] \right] \right]$$

$$\left[ \text{INDEX} \boxed{7} \text{D} \right]$$

$$\left[ \text{INDEX} k \right]$$

$$\left[ \text{COMPS} \langle \rangle \right]$$

$$\left[ \text{MOD} \langle \rangle \right]$$

$$\left[ \text{SEM} \left[ \text{MODE} \text{ ref} \right] \right]$$

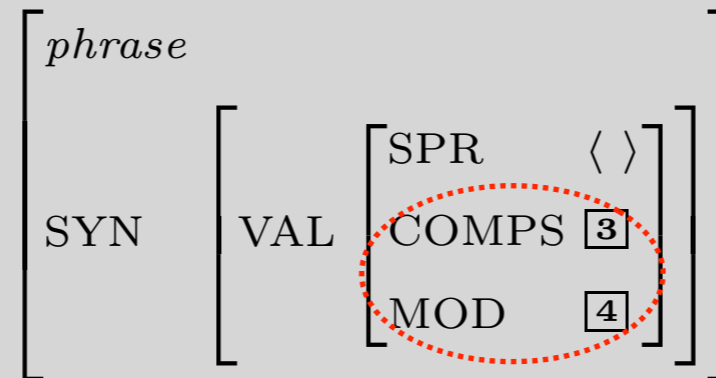
$$\left[ \text{INDEX} k \right]$$

$$\left[ \text{RESTR} \left\langle \left[ \text{RELN} \text{ cat} \right] \right\rangle \right]$$

$$\left[ \text{INSTANCE} k \right]$$

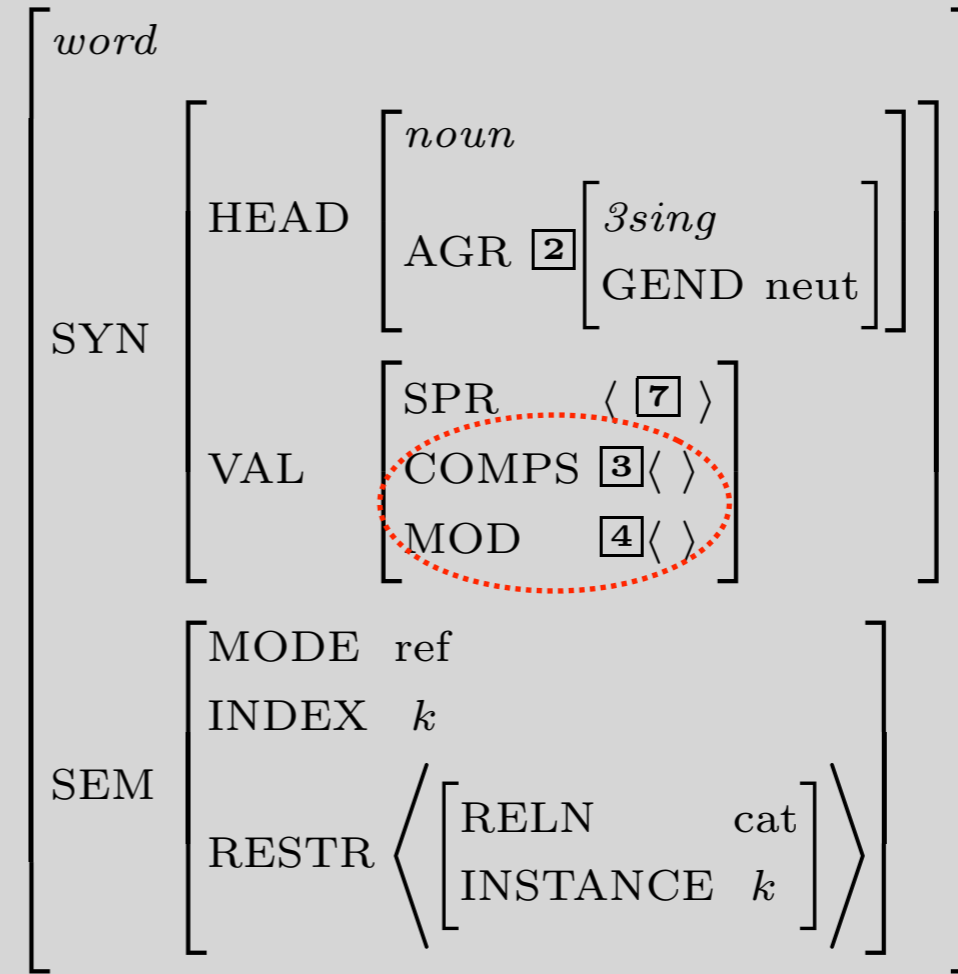
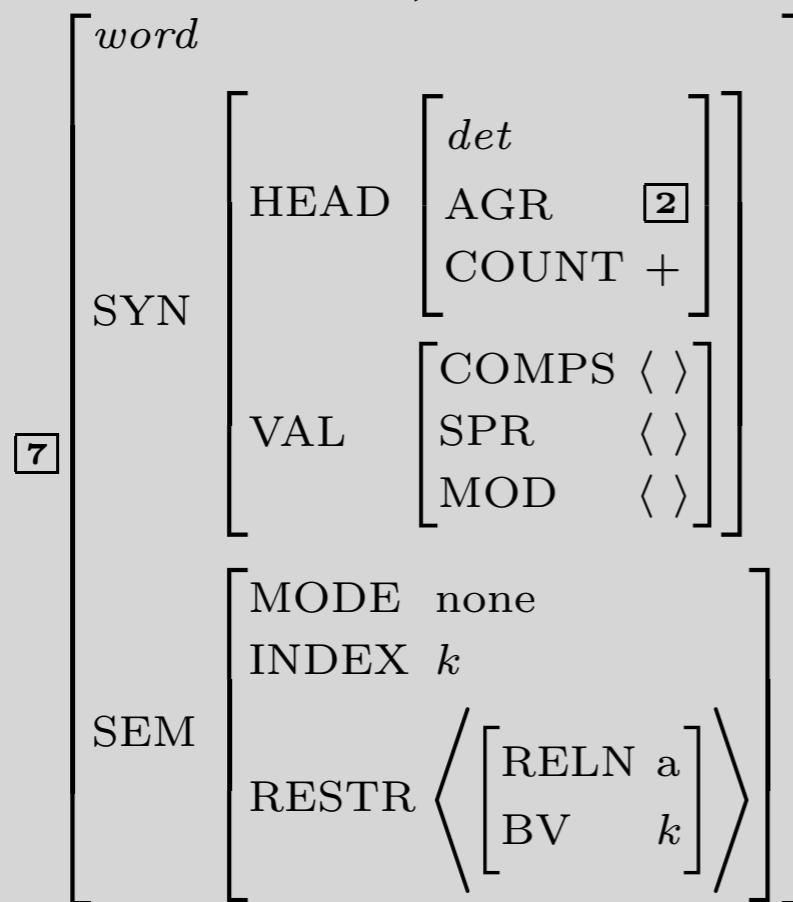


# Effects of the Valence Principle

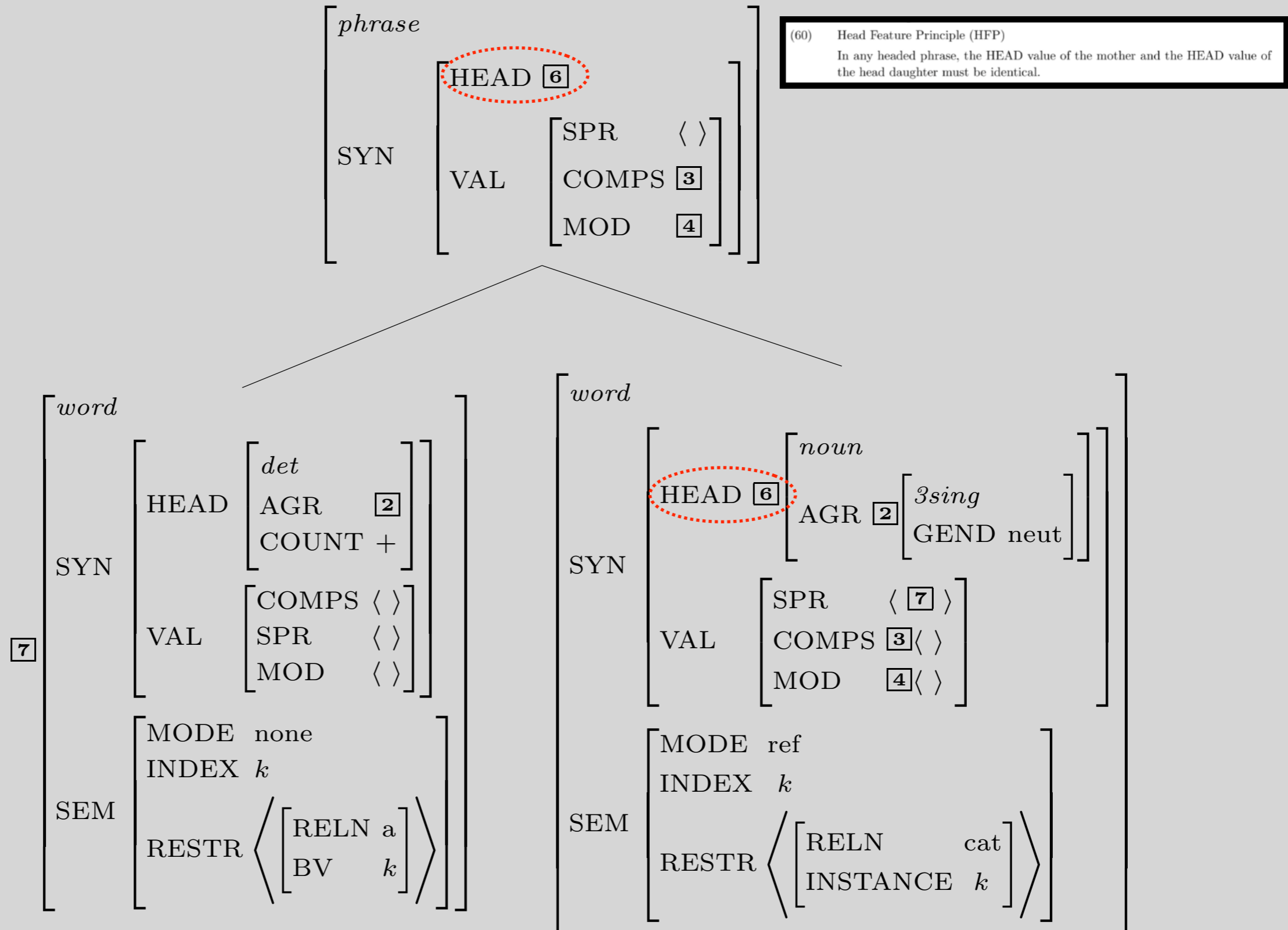


(61) Valence Principle  
 Unless the rule says otherwise, the mother's values for the VAL features (SPR, COMPS, and MOD) are identical to those of the head daughter.

(56) Head-Specifier Rule  
 $\left[ \begin{array}{c} \textit{phrase} \\ \text{SYN} \left[ \text{VAL} \left[ \text{SPR} \langle \rangle \right] \right] \right] \rightarrow \square \text{H} \left[ \text{SYN} \left[ \text{VAL} \left[ \begin{array}{c} \text{SPR} \langle \square \rangle \\ \text{COMPS} \langle \rangle \end{array} \right] \right] \right]$   
 A phrase can consist of a (lexical or phrasal) head preceded by its specifier.

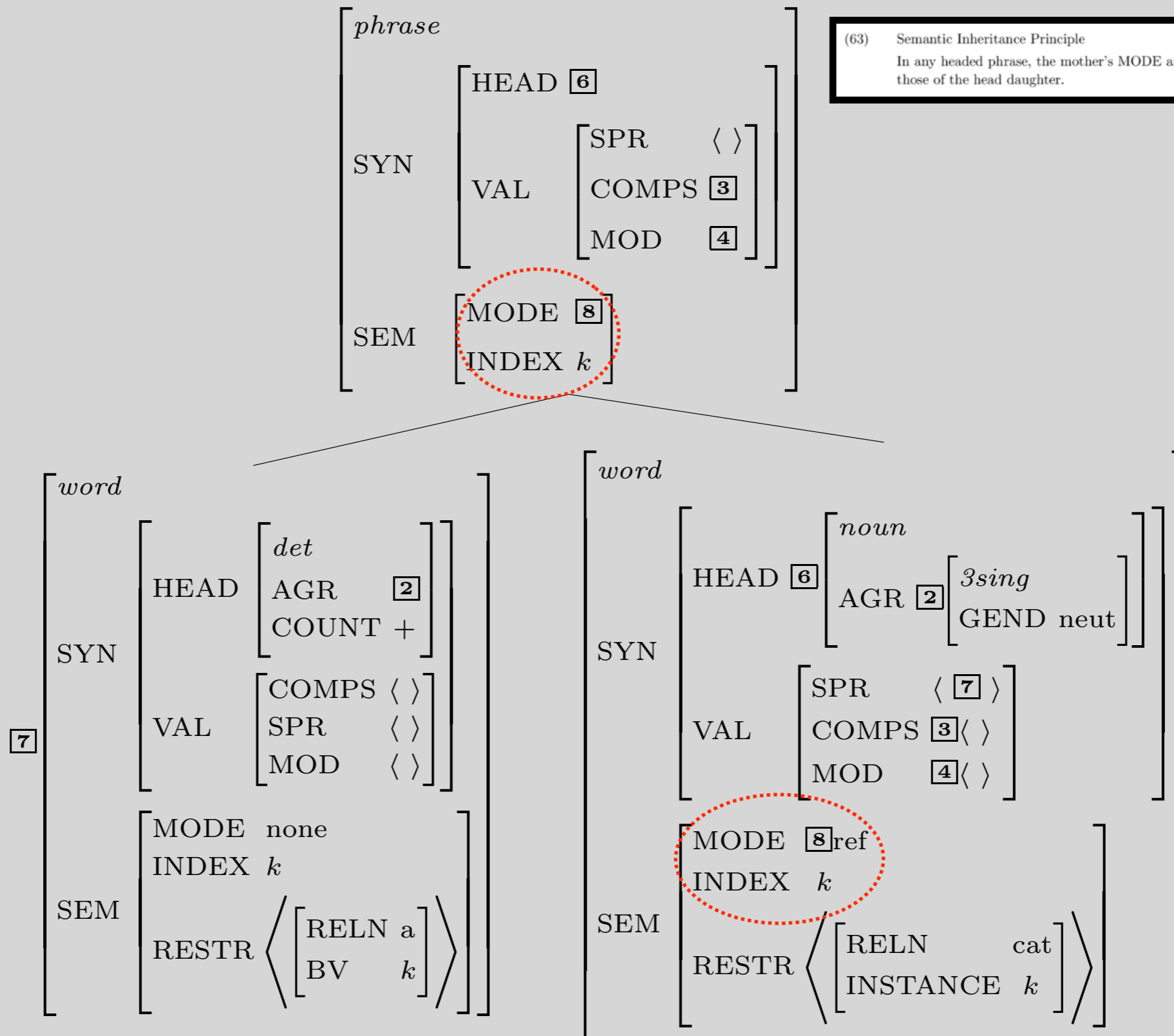


# Effects of the Head Feature Principle



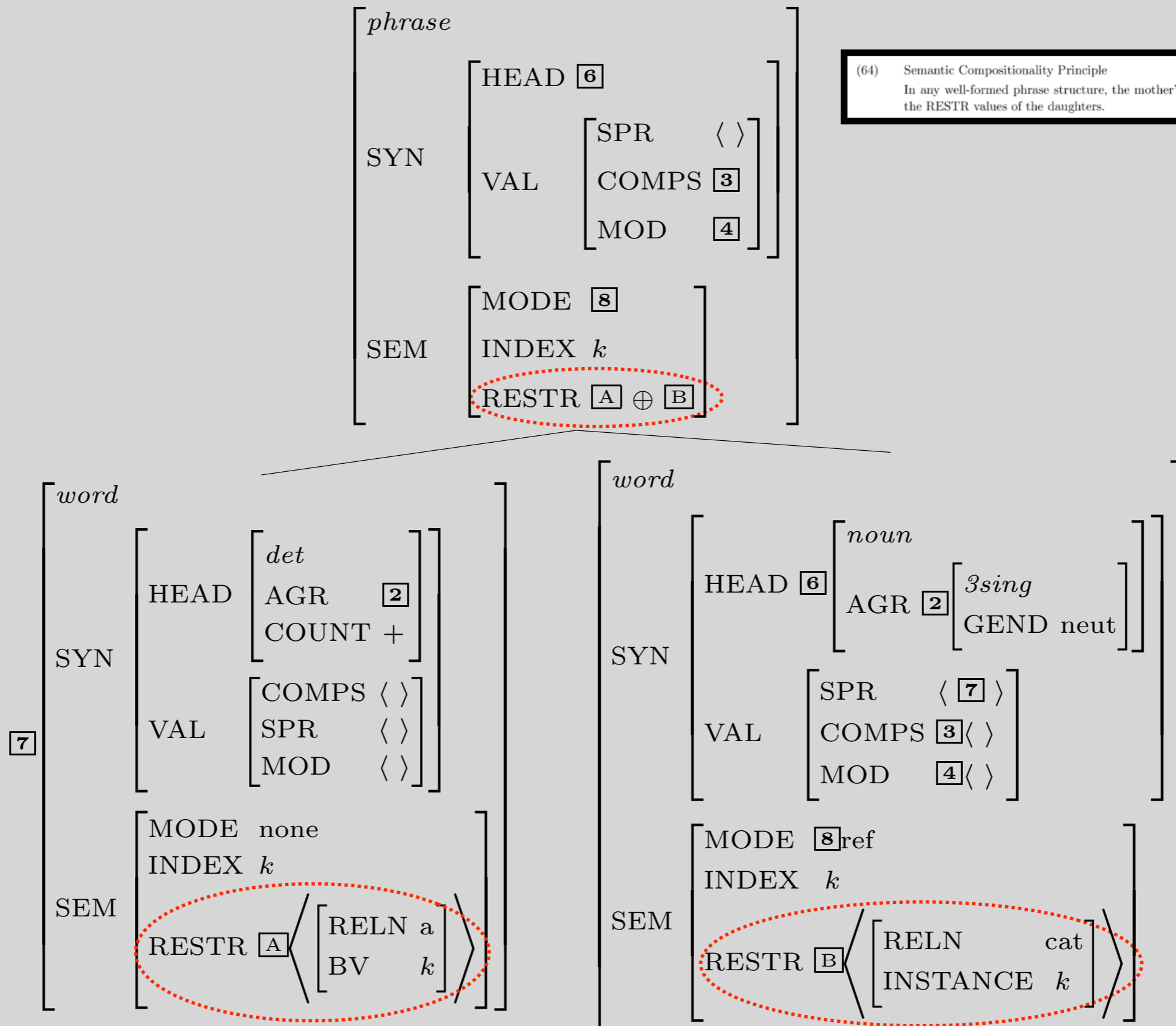
# Effects of the Semantic Inheritance Principle

(63) Semantic Inheritance Principle  
 In any headed phrase, the mother's MODE and INDEX values are identical to those of the head daughter.

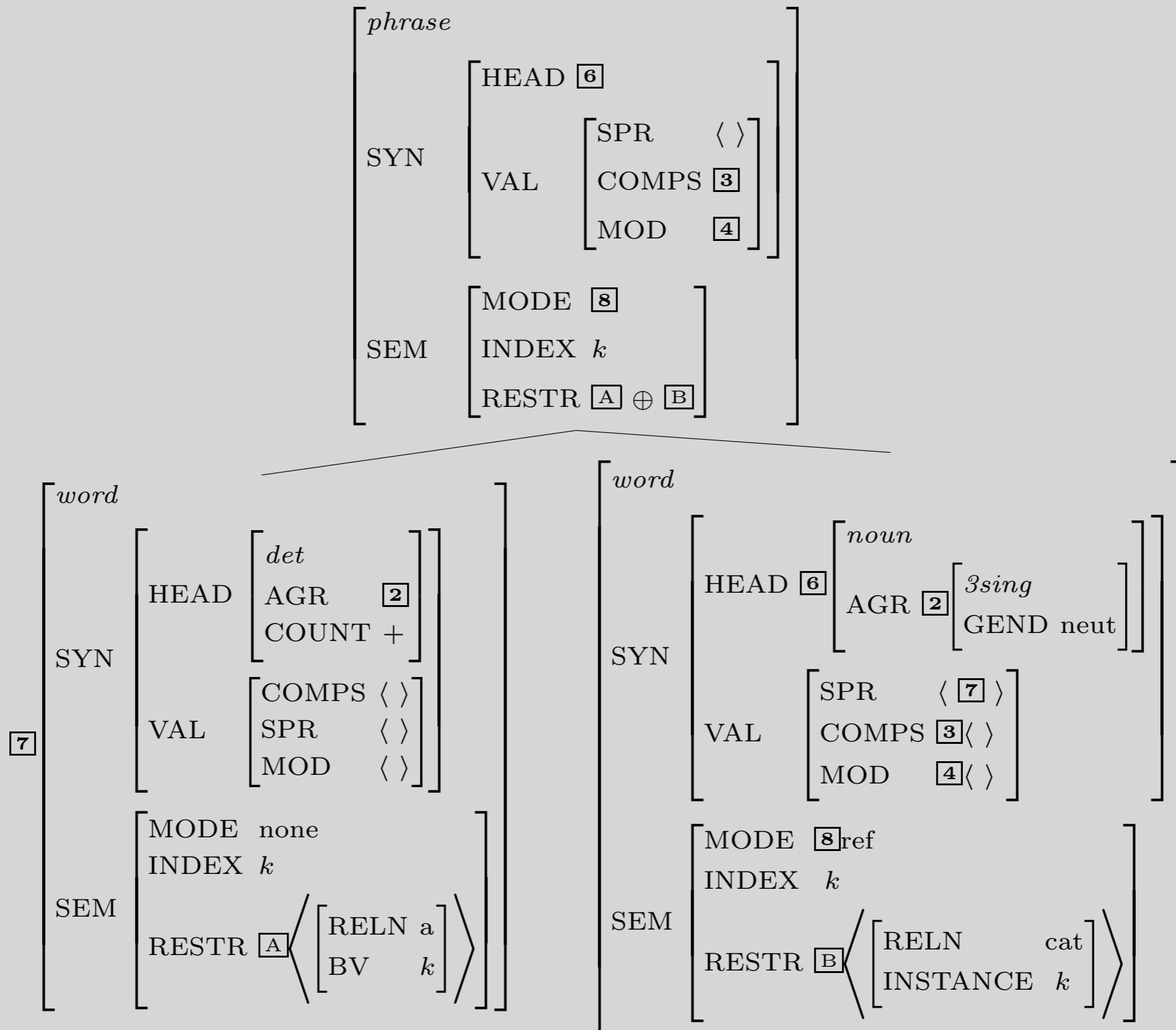


# Effects of the Semantic Compositionality Principle

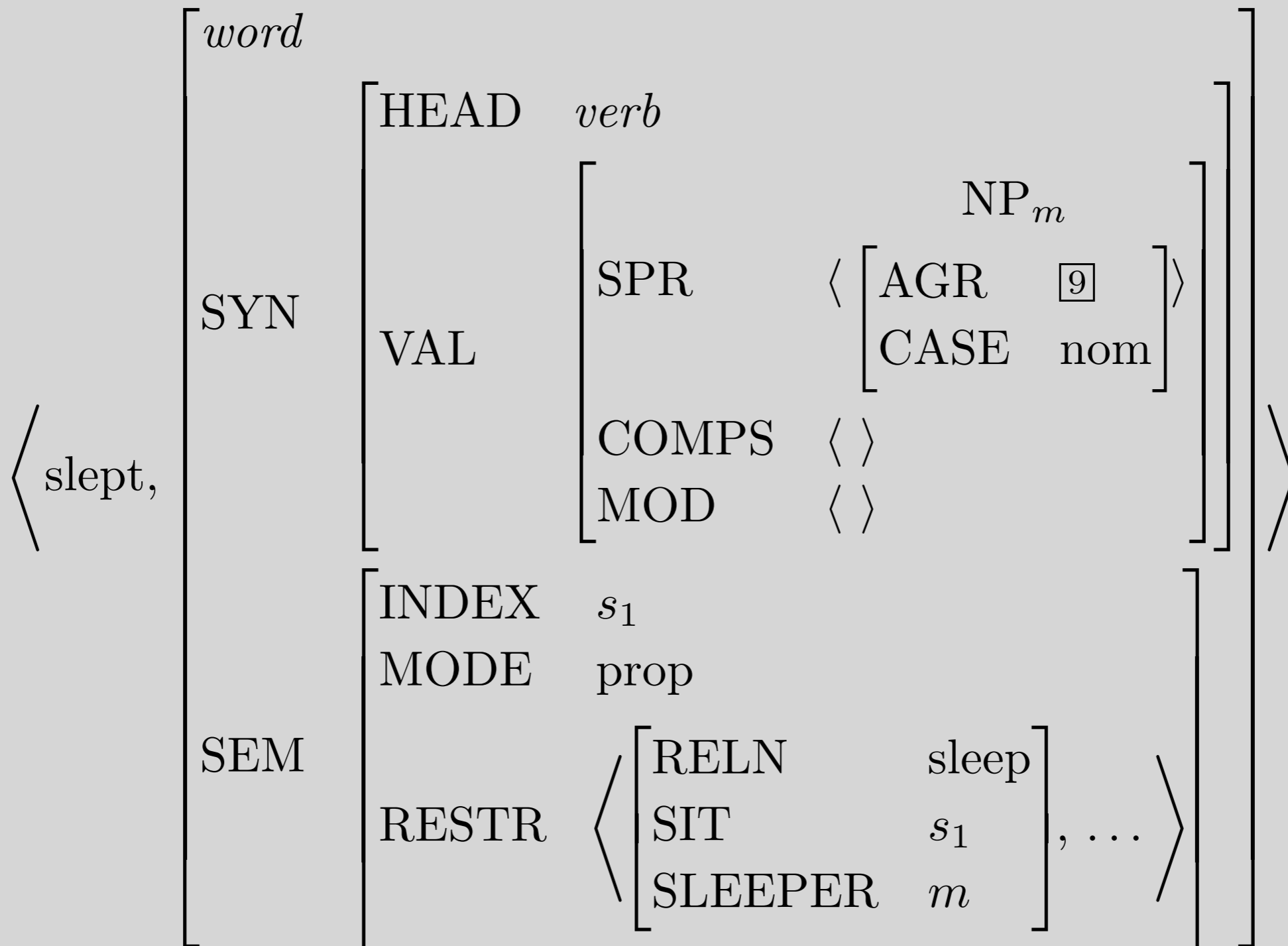
(64) Semantic Compositionality Principle  
 In any well-formed phrase structure, the mother's RESTR value is the sum of the RESTR values of the daughters.



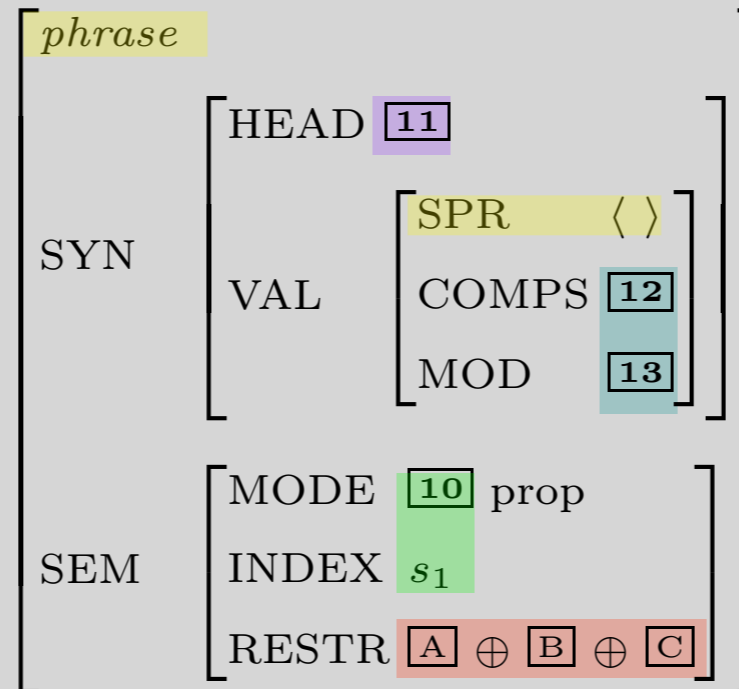
# Is the Mother Node Now Completely Specified?



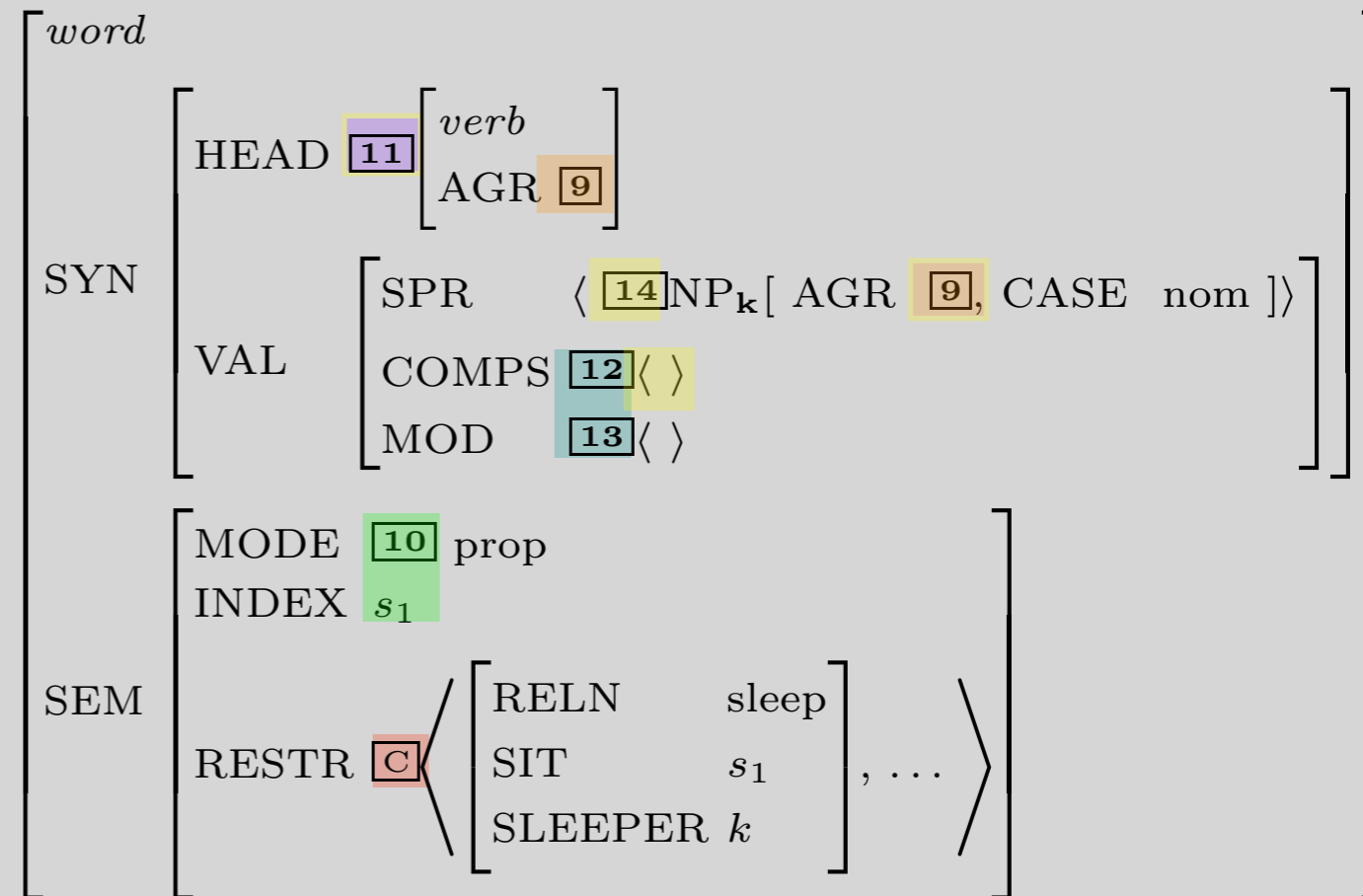
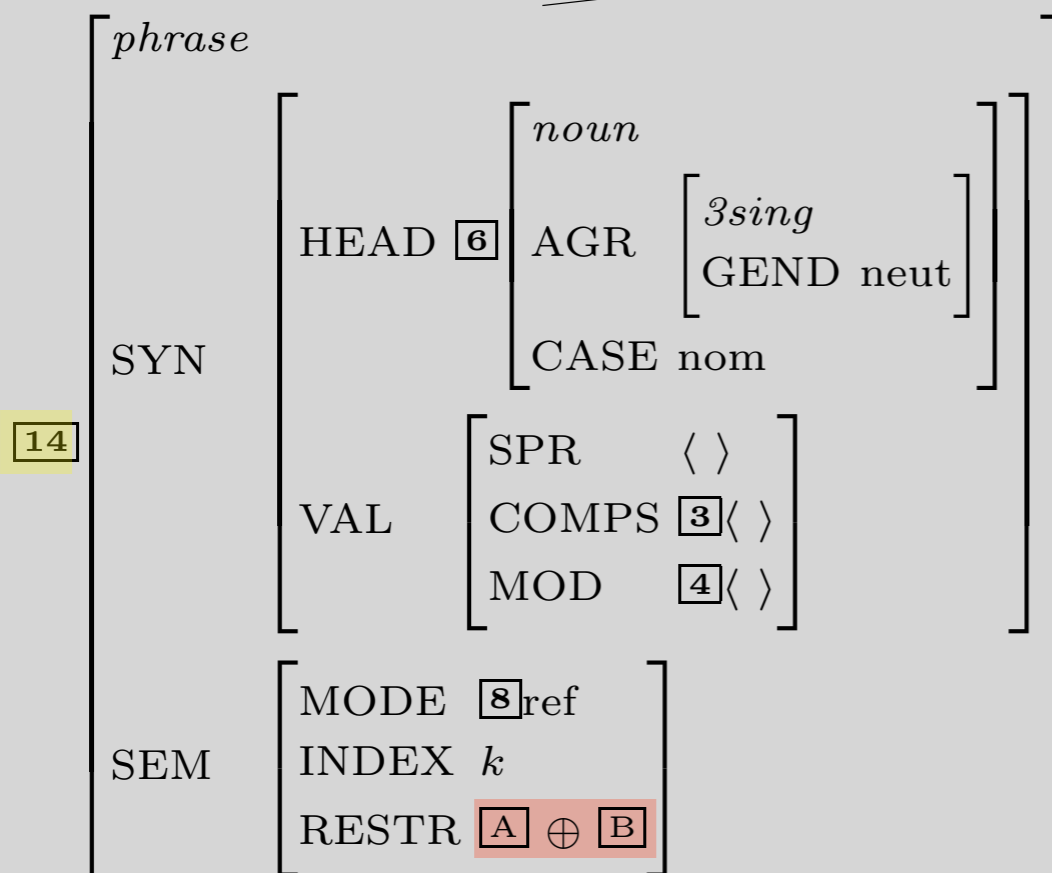
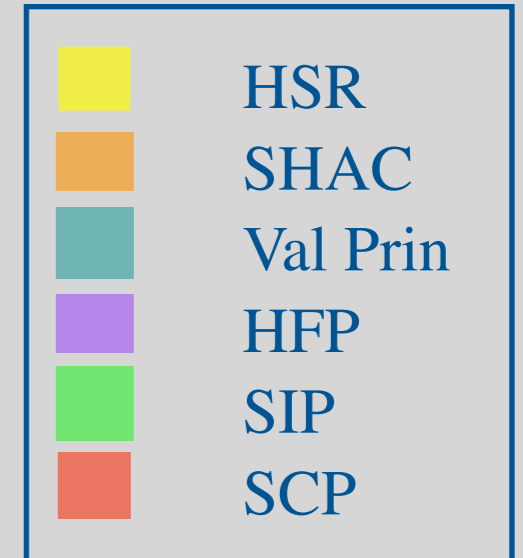
# Lexical Entry for *slept*



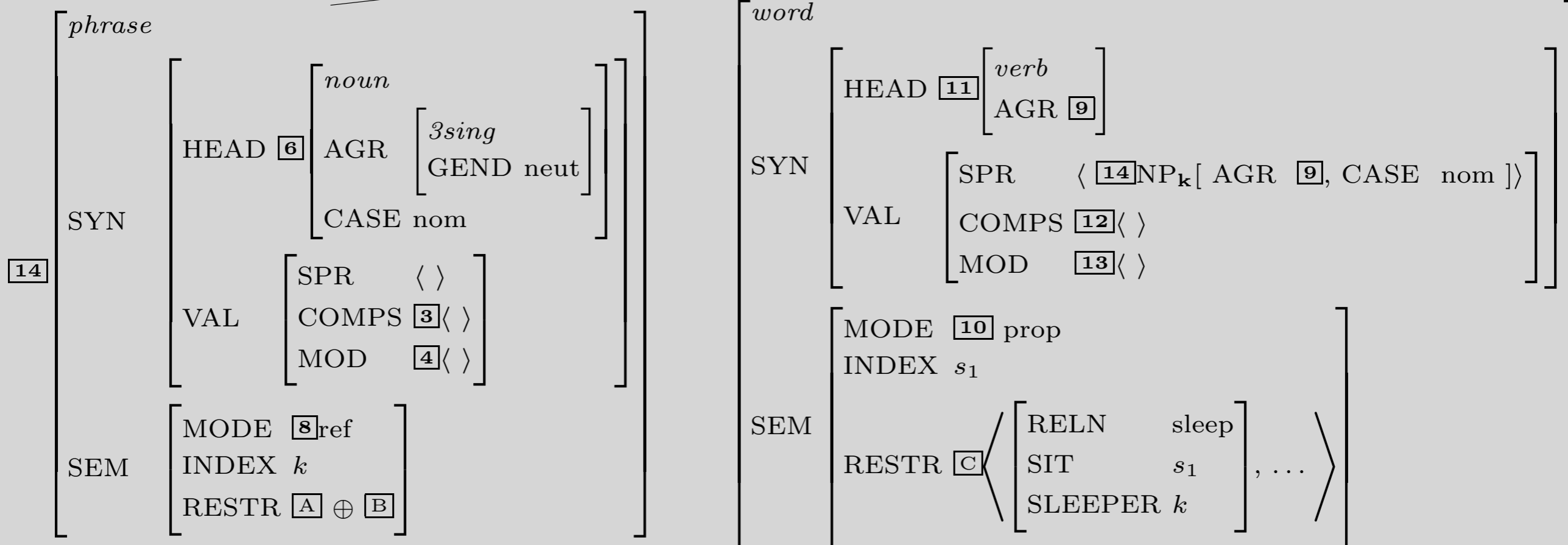
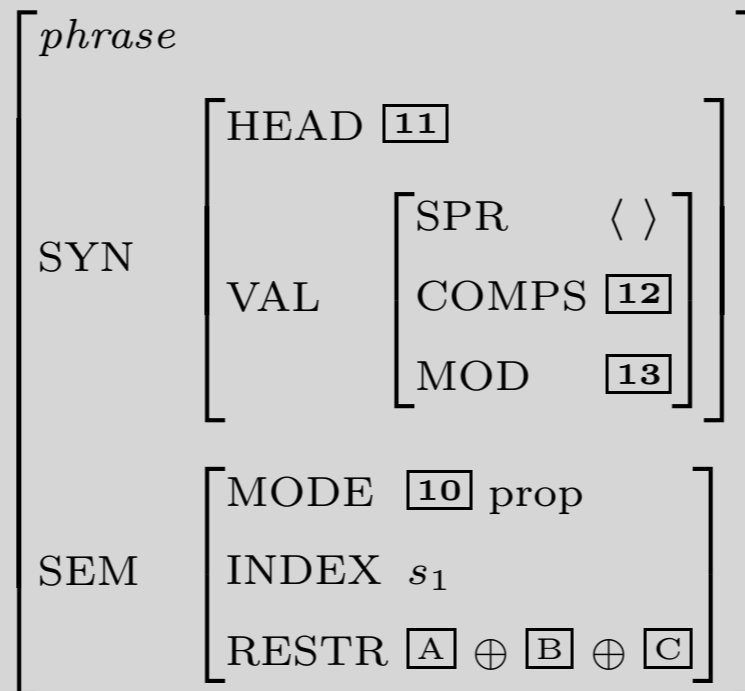
# Another Head-Specifier Phrase



## Key

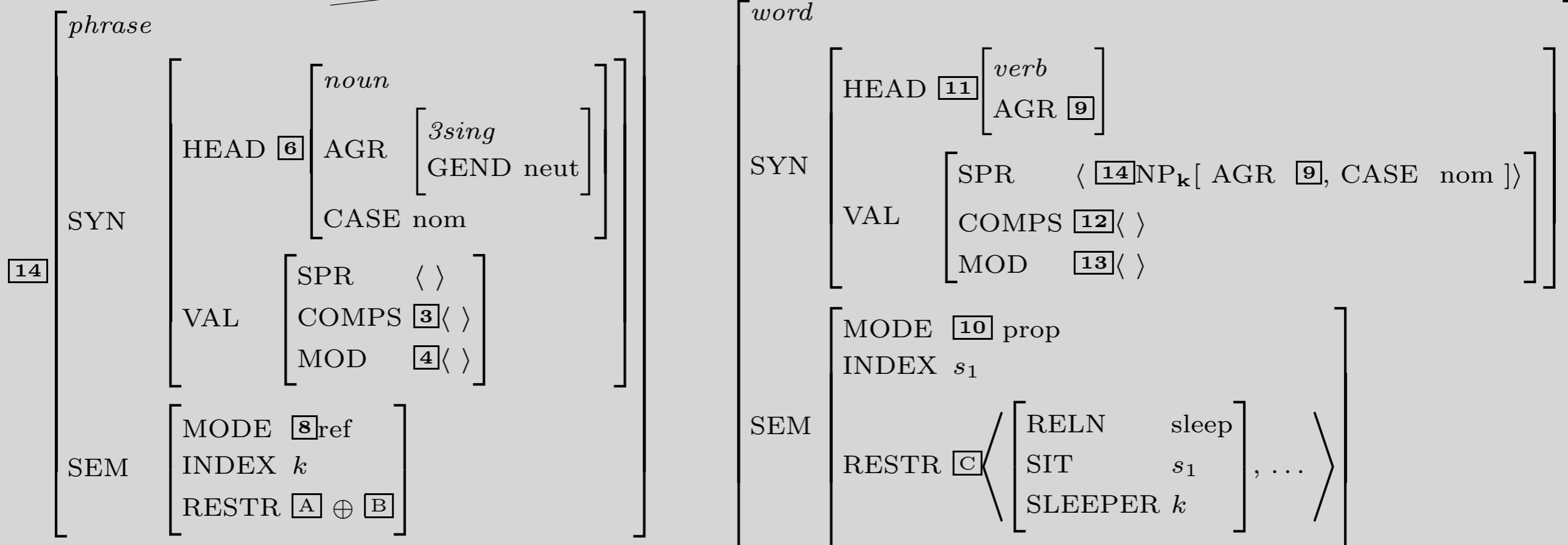
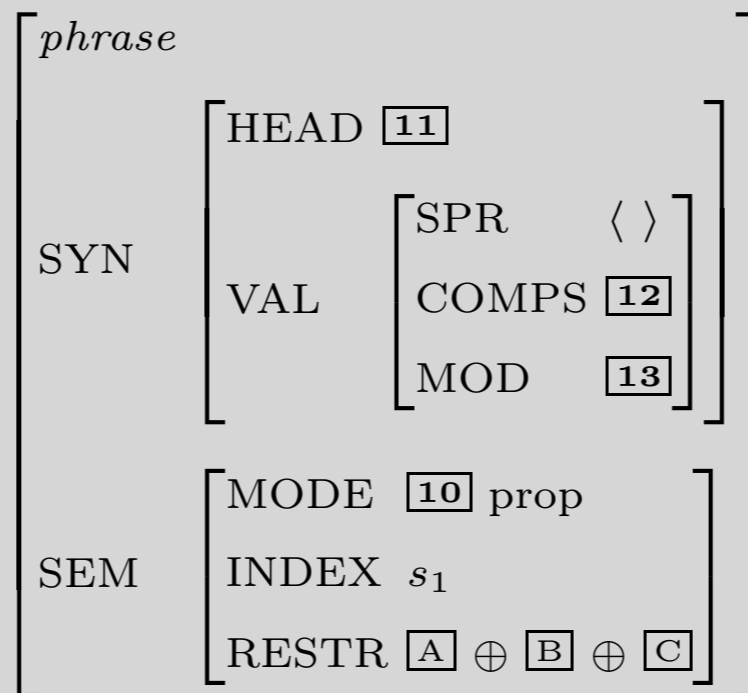


# Is this description fully specified?





# Does the top node satisfy the initial symbol?



# Does the top node satisfy the initial symbol?

(55)

$$S = \left[ \text{SYN} \left[ \begin{array}{l} \text{HEAD } \textit{verb} \\ \text{VAL} \left[ \begin{array}{l} \text{COMPS } \langle \rangle \\ \text{SPR} \langle \rangle \end{array} \right] \end{array} \right] \right]$$

$$\left[ \begin{array}{l} \textit{phrase} \\ \text{SYN} \left[ \begin{array}{l} \text{HEAD } \boxed{11} \\ \text{VAL} \left[ \begin{array}{l} \text{SPR } \langle \rangle \\ \text{COMPS } \boxed{12} \\ \text{MOD } \boxed{13} \end{array} \right] \end{array} \right] \\ \text{SEM} \left[ \begin{array}{l} \text{MODE } \boxed{10} \textit{prop} \\ \text{INDEX } s_1 \\ \text{RESTR } \boxed{A} \oplus \boxed{B} \oplus \boxed{C} \end{array} \right] \end{array} \right]$$

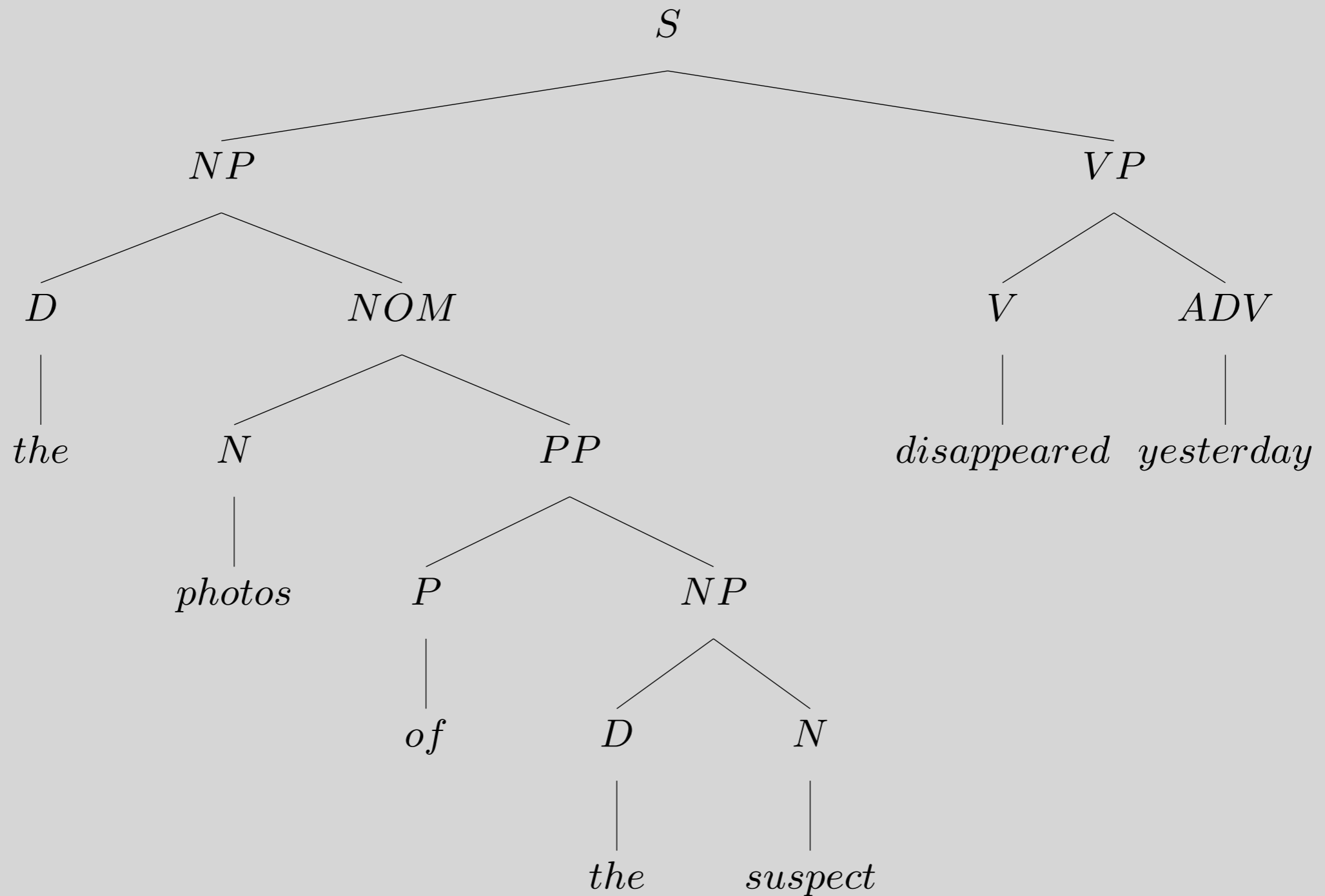
$$\boxed{14} \left[ \begin{array}{l} \textit{phrase} \\ \text{SYN} \left[ \begin{array}{l} \text{HEAD } \boxed{6} \left[ \begin{array}{l} \textit{noun} \\ \text{AGR} \left[ \begin{array}{l} \textit{3sing} \\ \text{GEND } \textit{neut} \end{array} \right] \\ \text{CASE } \textit{nom} \end{array} \right] \\ \text{VAL} \left[ \begin{array}{l} \text{SPR } \langle \rangle \\ \text{COMPS } \boxed{3} \langle \rangle \\ \text{MOD } \boxed{4} \langle \rangle \end{array} \right] \end{array} \right] \\ \text{SEM} \left[ \begin{array}{l} \text{MODE } \boxed{8} \textit{ref} \\ \text{INDEX } k \\ \text{RESTR } \boxed{A} \oplus \boxed{B} \end{array} \right] \end{array} \right]$$

$$\left[ \begin{array}{l} \textit{word} \\ \text{SYN} \left[ \begin{array}{l} \text{HEAD } \boxed{11} \left[ \begin{array}{l} \textit{verb} \\ \text{AGR } \boxed{9} \end{array} \right] \\ \text{VAL} \left[ \begin{array}{l} \text{SPR } \langle \boxed{14} \text{NP}_k [ \text{AGR } \boxed{9}, \text{CASE } \textit{nom} ] \rangle \\ \text{COMPS } \boxed{12} \langle \rangle \\ \text{MOD } \boxed{13} \langle \rangle \end{array} \right] \end{array} \right] \\ \text{SEM} \left[ \begin{array}{l} \text{MODE } \boxed{10} \textit{prop} \\ \text{INDEX } s_1 \\ \text{RESTR } \boxed{C} \left\langle \begin{array}{l} \text{RELN } \textit{sleep} \\ \text{SIT } s_1 \\ \text{SLEEPER } k \end{array} \right\rangle, \dots \end{array} \right] \end{array} \right]$$

# RESTR of the S node

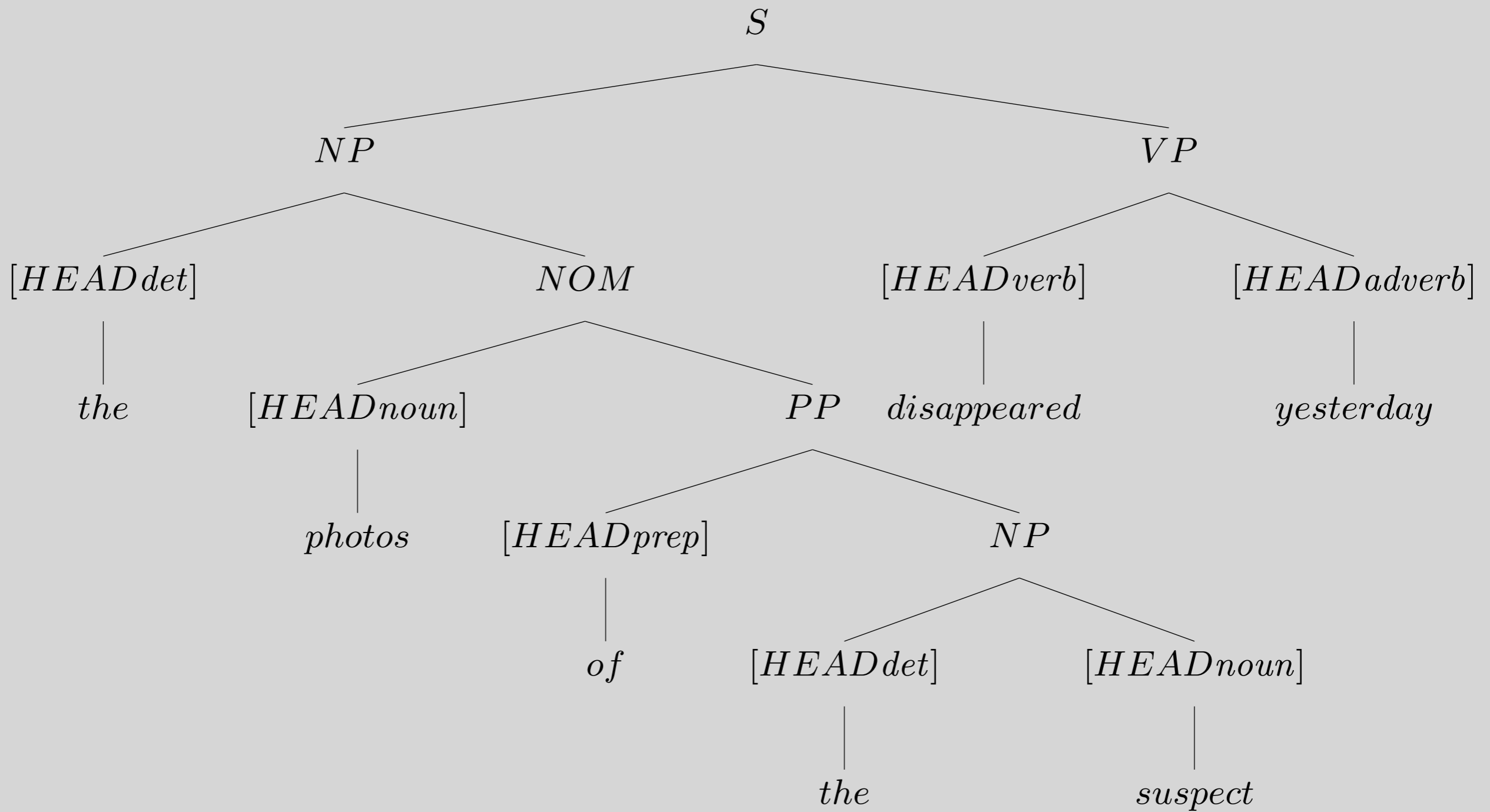
$$\left\langle \begin{bmatrix} \text{RELN} & a \\ \text{BV} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{cat} \\ \text{INST} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{sleep} \\ \text{SIT} & s_1 \\ \text{SLEEPER} & k \end{bmatrix}, \dots \right\rangle$$

# Another Example

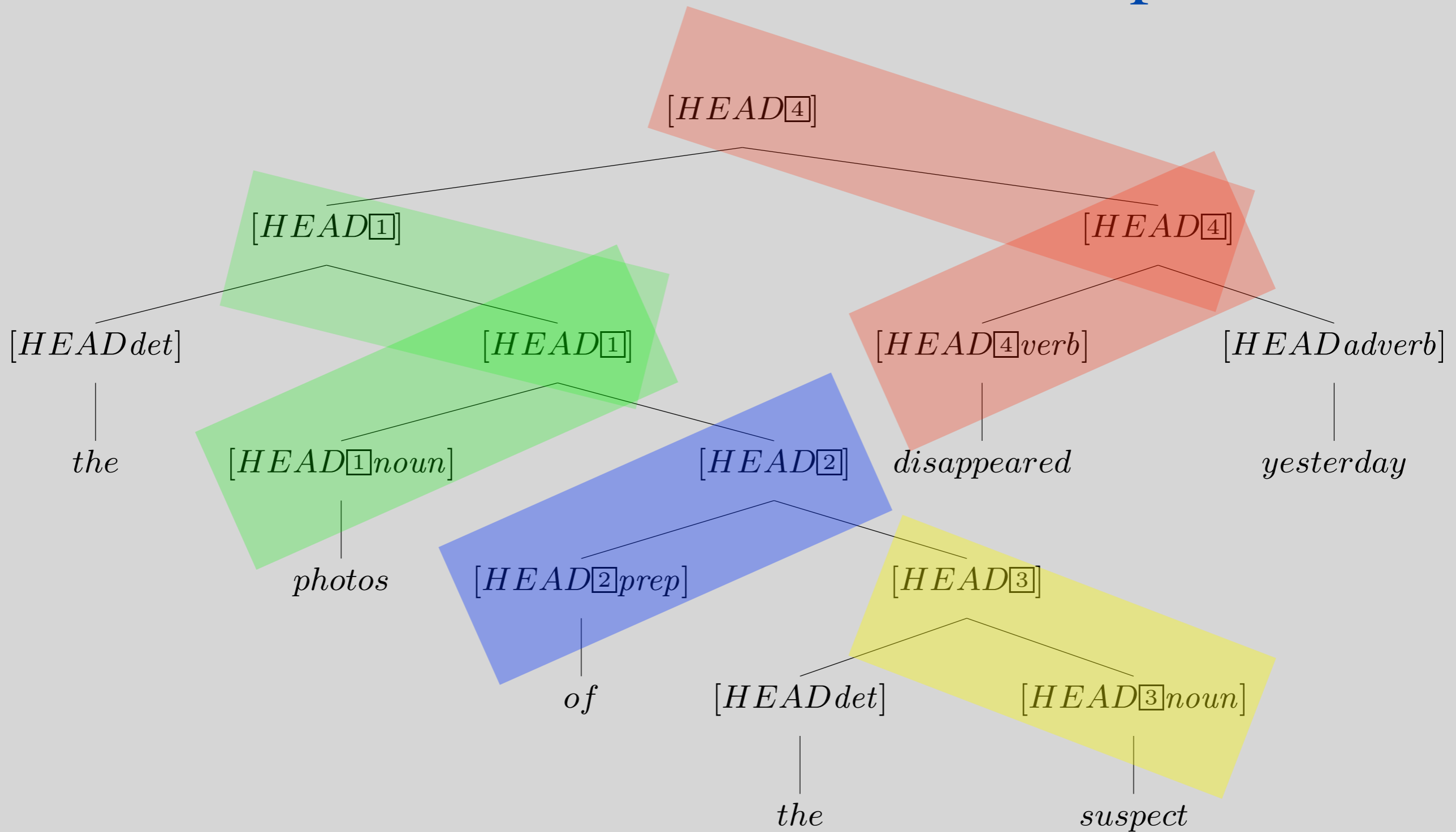


What rule builds each subtree?

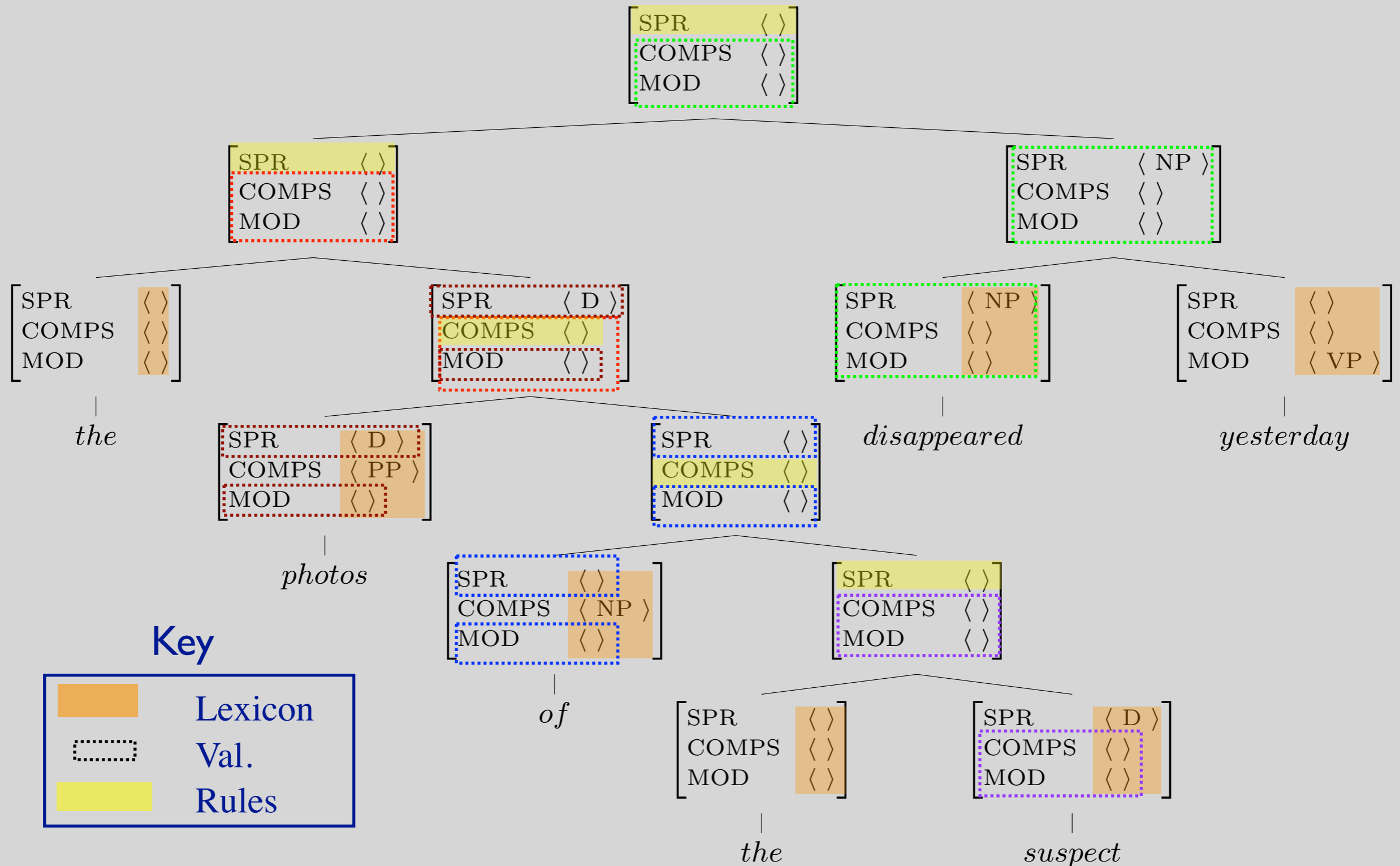
# Head Features from Lexical Entries



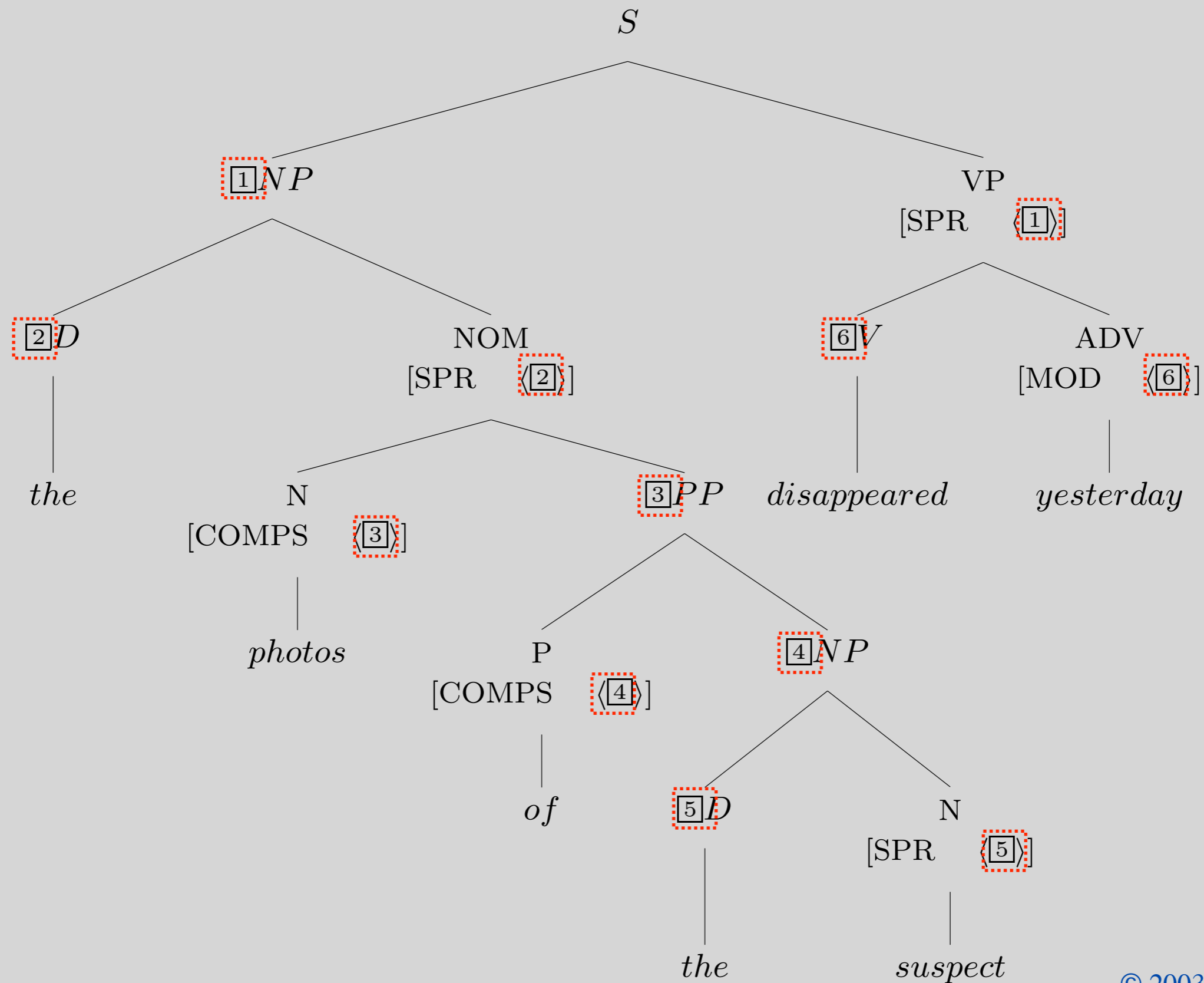
# Head Features from Lexical Entries, plus HFP



# Valence Features: Lexicon, Rules, and the Valence Principle

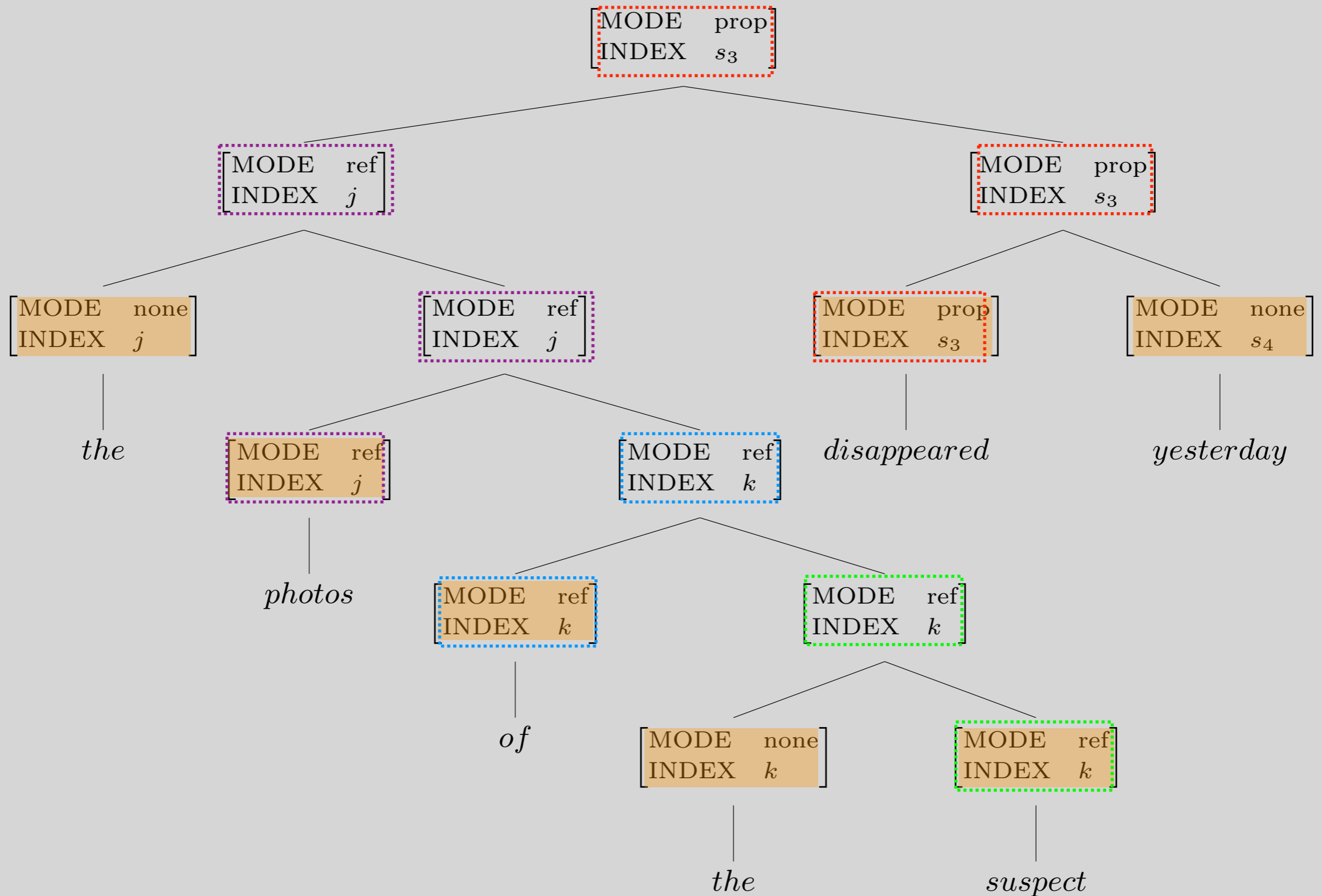


# Required Identities: Grammar Rules

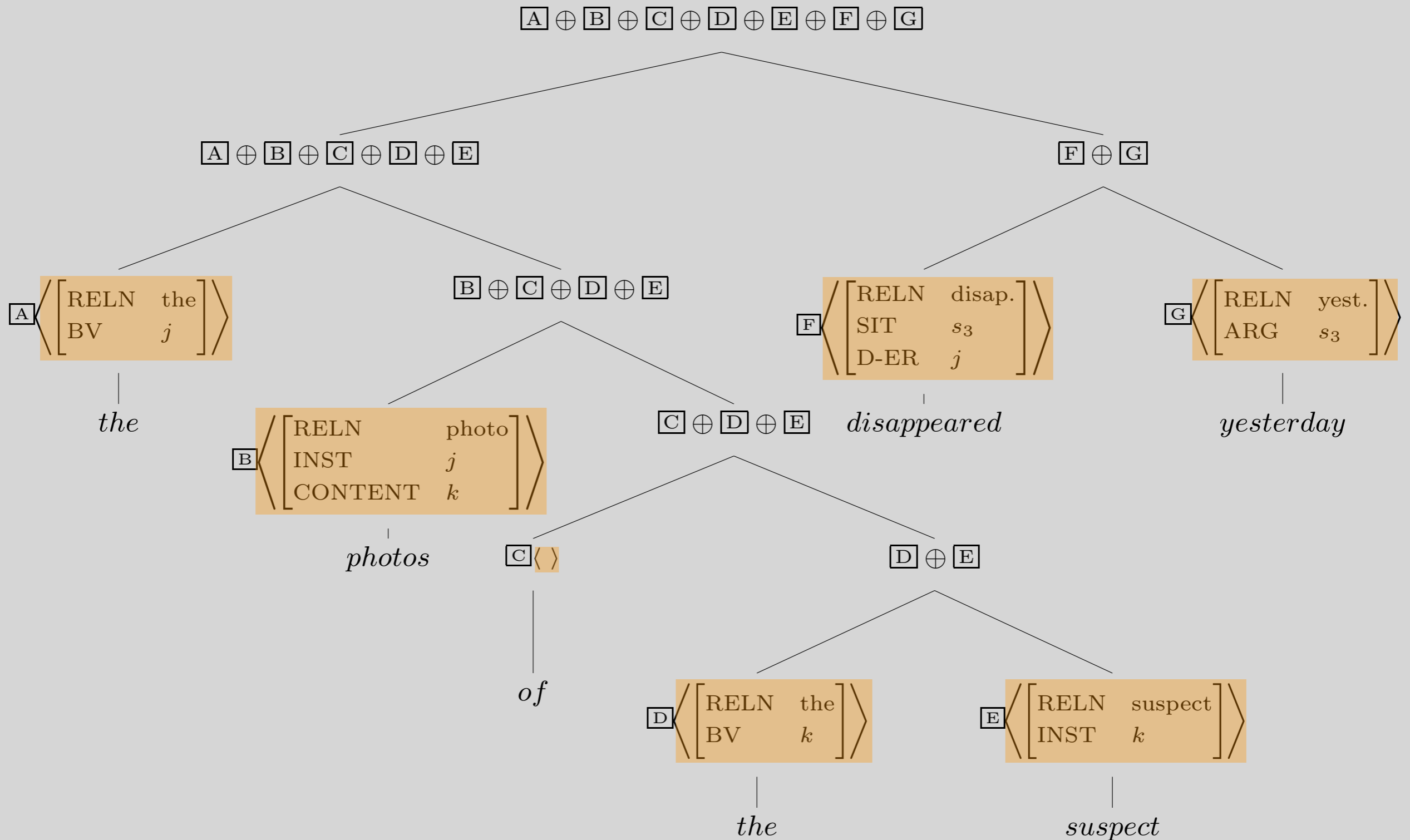




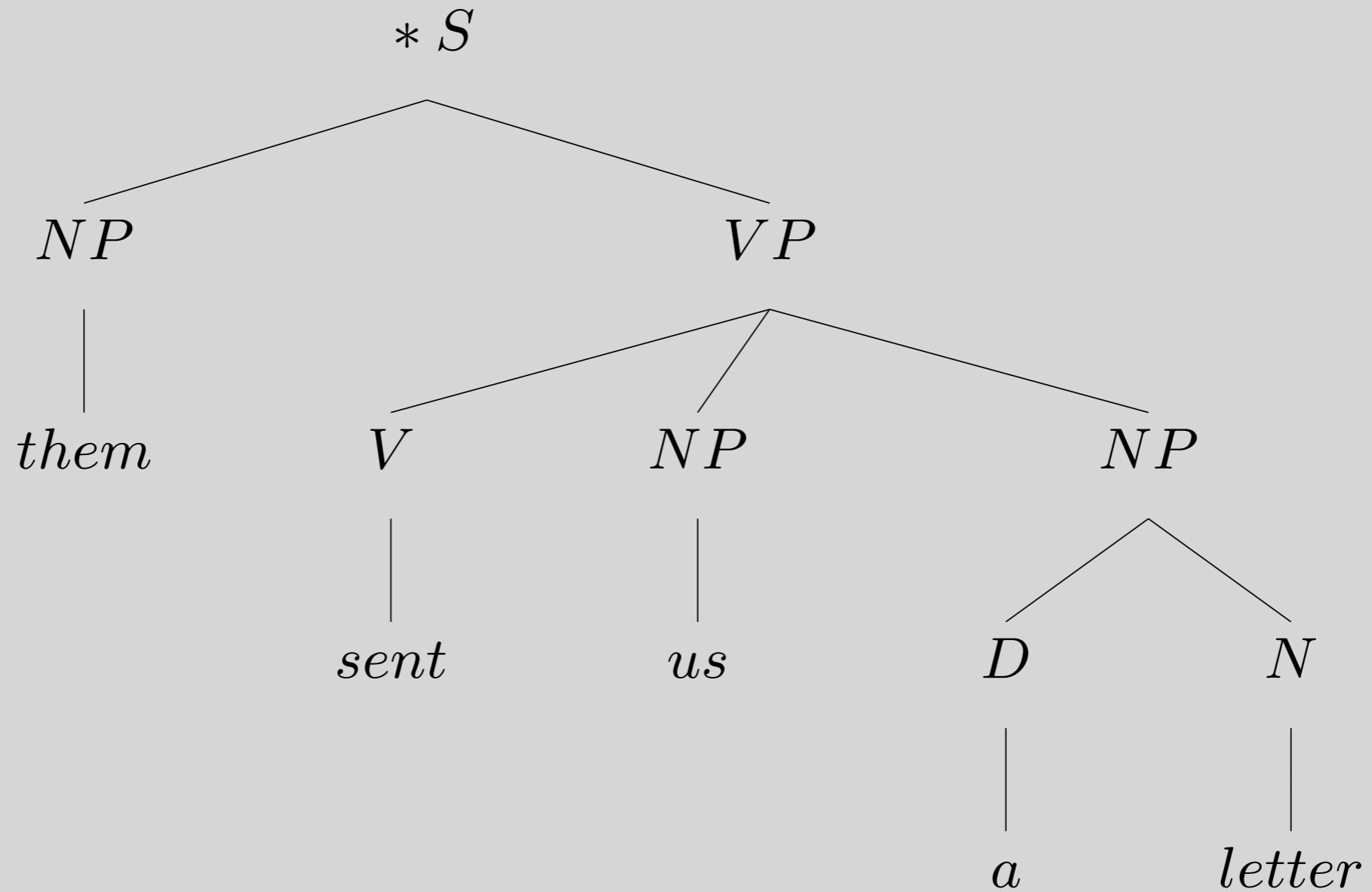
# Two Semantic Features: the Lexicon & SIP



# RESTR Values and the SCP

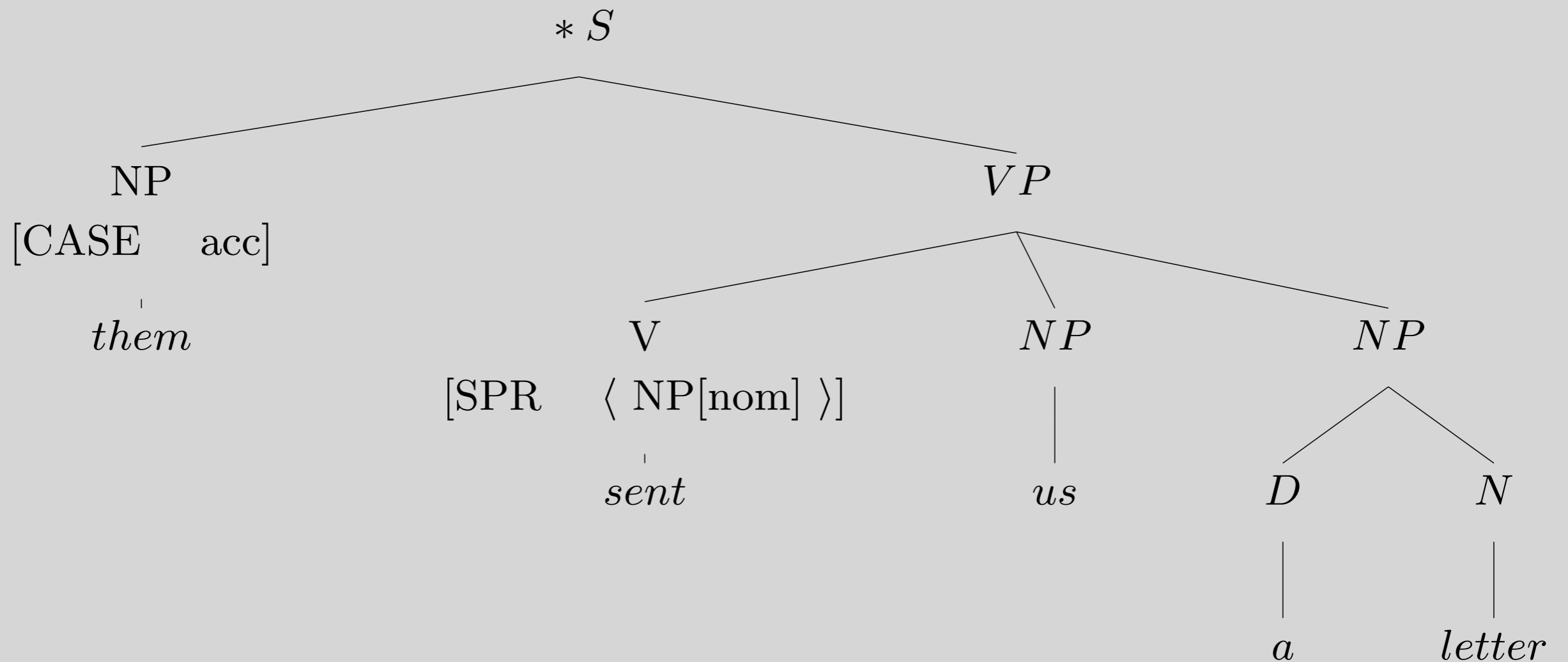


# An Ungrammatical Example



What's wrong with this sentence?

# An Ungrammatical Example

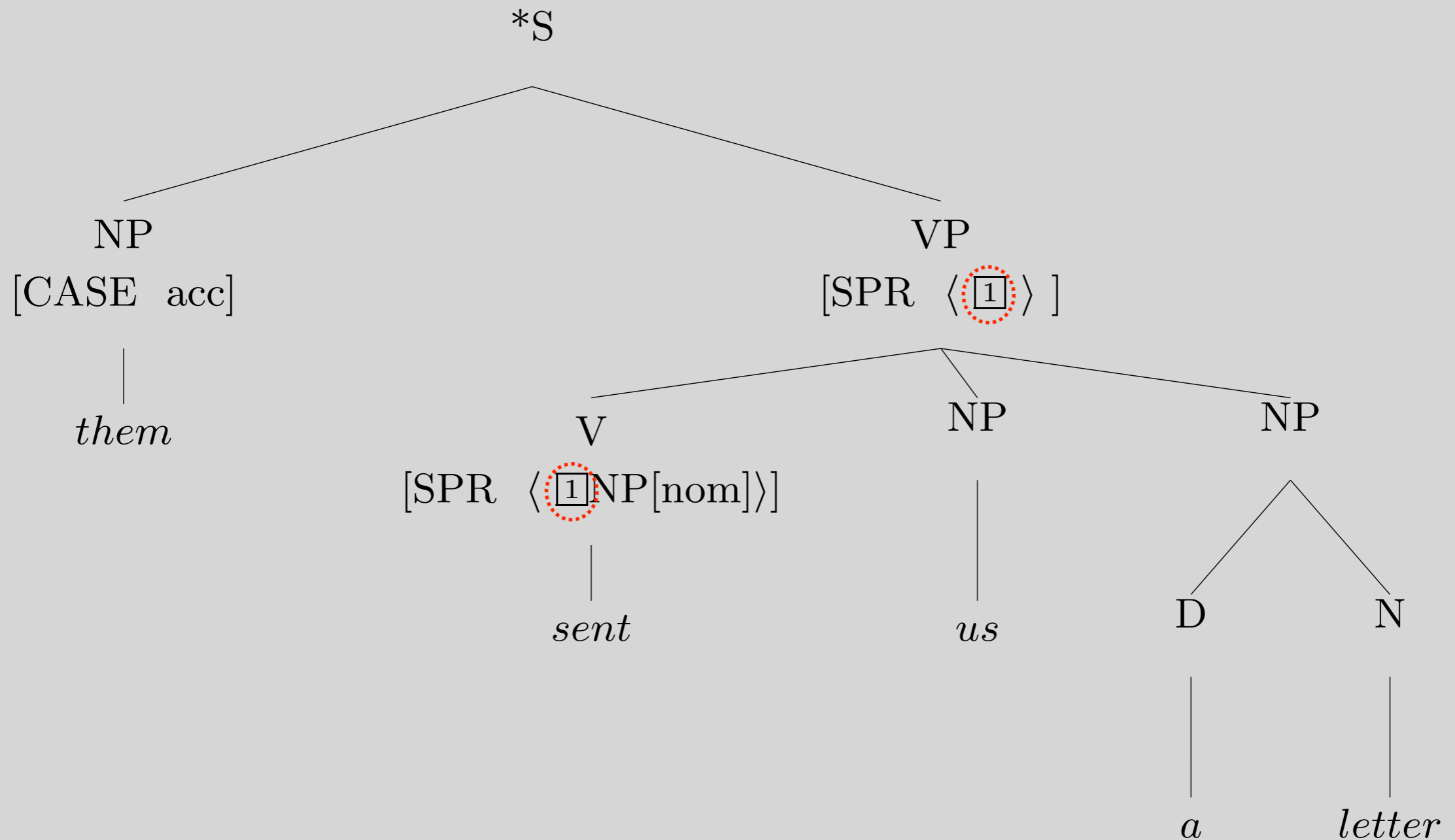


What's wrong with this sentence?

So what?

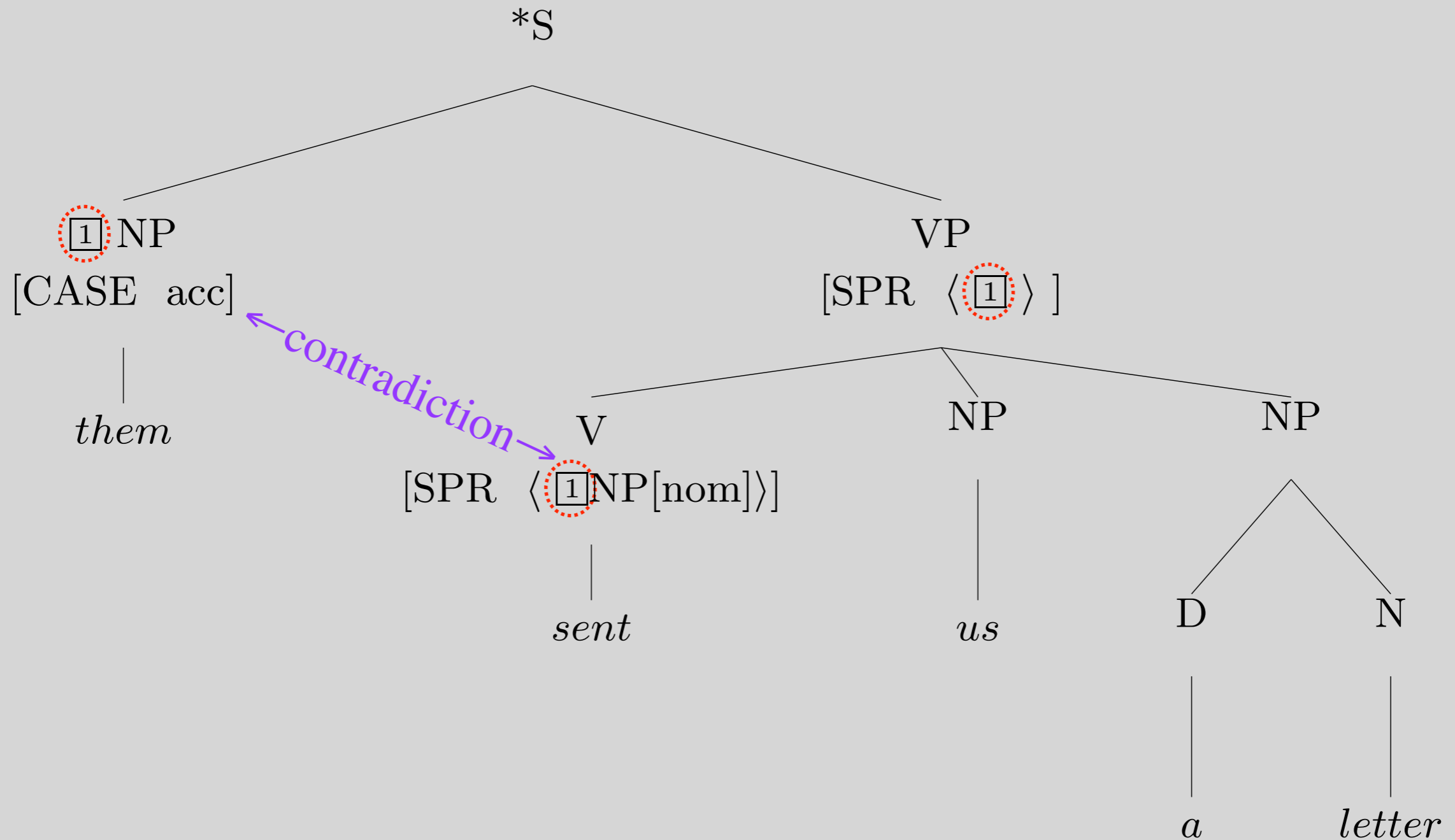
# An Ungrammatical Example

## The Valence Principle



# An Ungrammatical Example

## Head Specifier Rule



# Exercise in Critical Thinking

- Our grammar has come a long way since Ch 2, as we've added ways of representing different kinds of information:
  - generalizations across categories
  - semantics
  - particular linguistic phenomena: valence, agreement, modification
- What else might we add? What facts about language are as yet unrepresented in our model?

# Overview

- What we're trying to do
- The pieces of our grammar
- Two extended examples
- Reflection on what we've done, what we still have to do