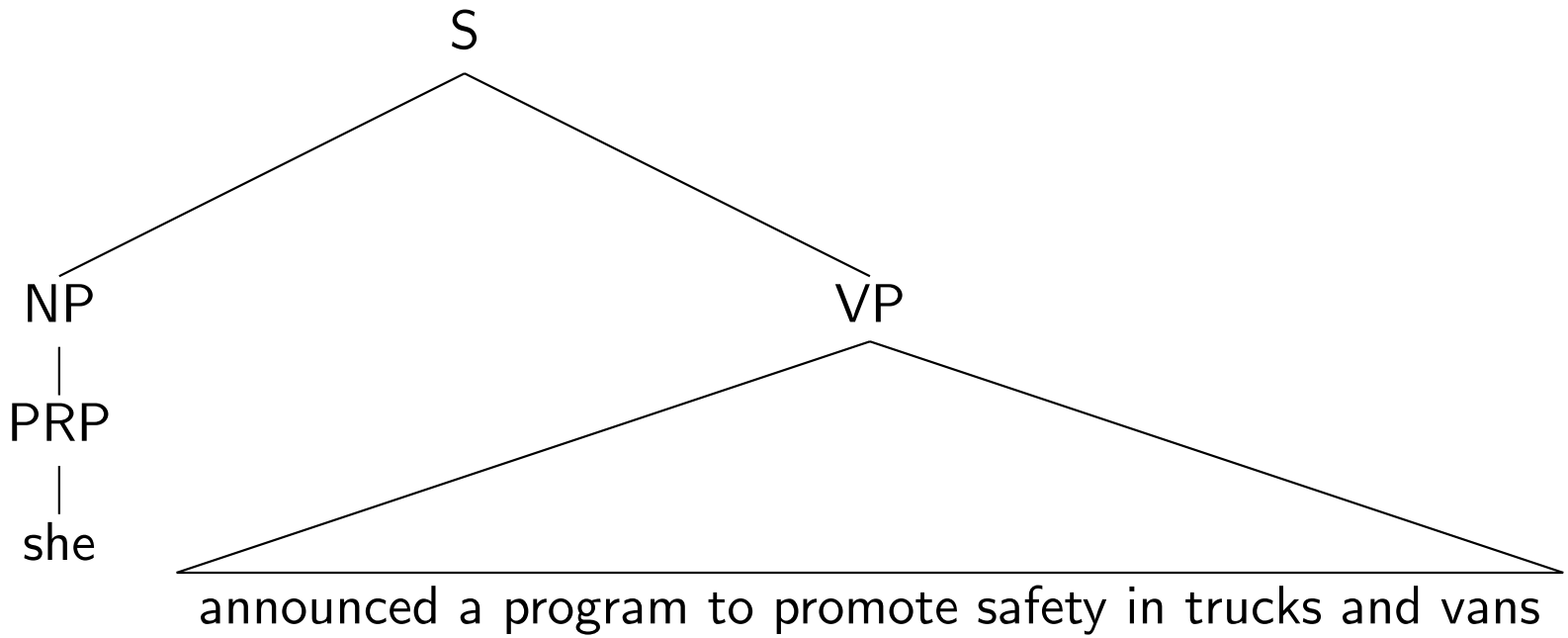
Master in Artificial Intelligence

# Introduction to Human Language Technologies
# 8. Syntactic parsing: grammars


UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Facultat d'Informàtica de Barcelona

FIB

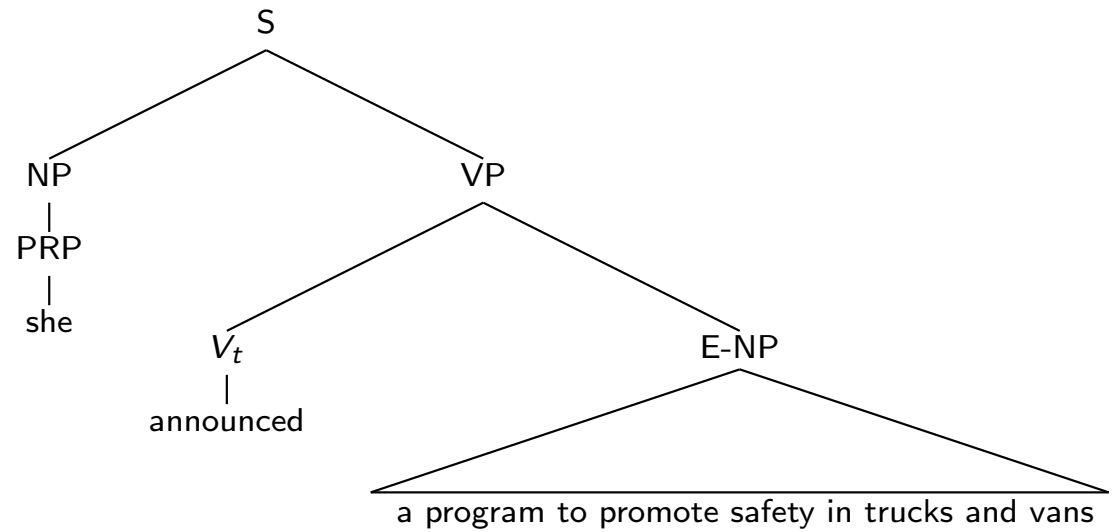
# Exercise 1




- Give 3 possible interpretations in the form of parse trees
- Provide a CFG to get at least one of the interpretations

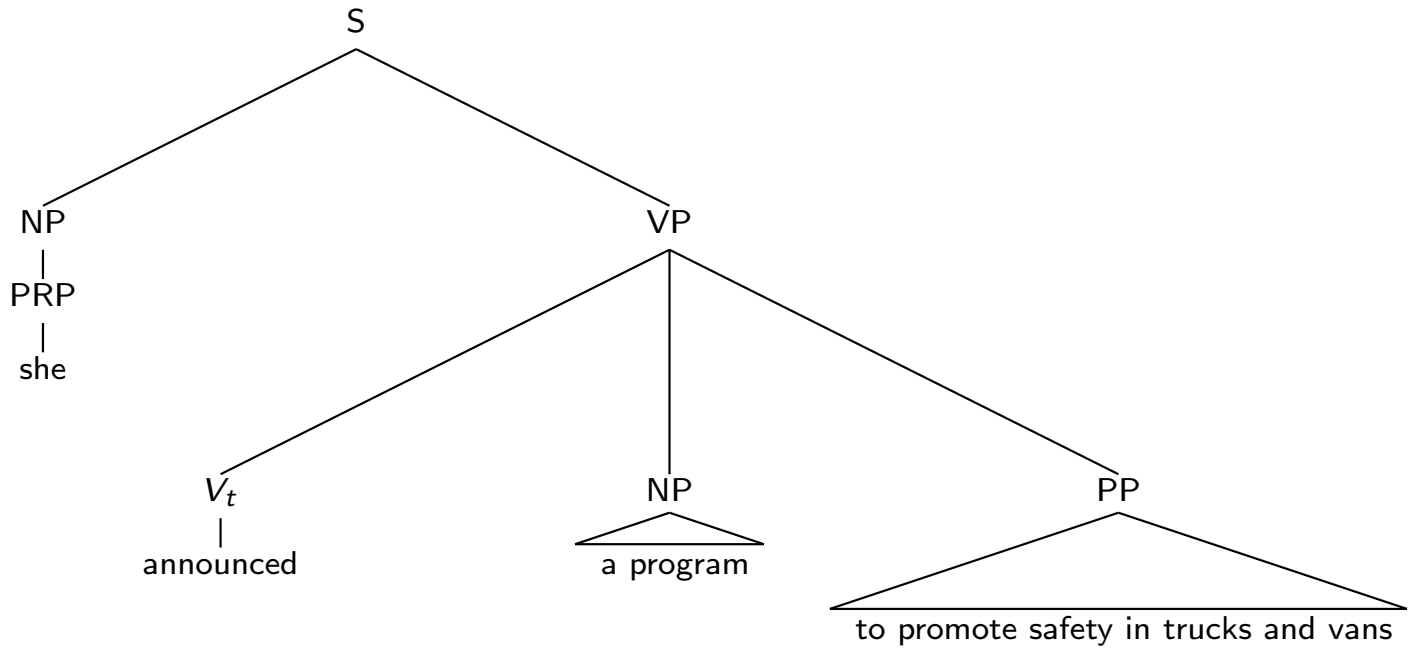
# Exercise 1: 3 possible interpretions in the form of parse trees

- She made an announcement of a program. The program promoted safety in trucks and vans.



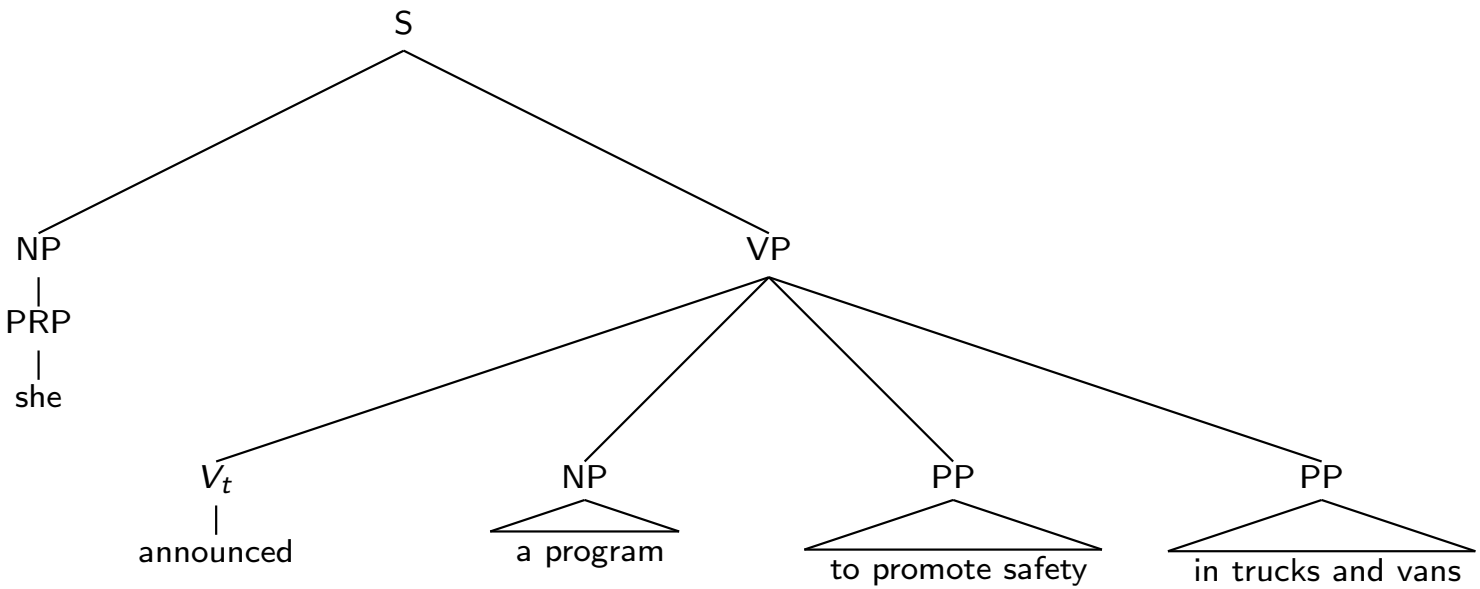
# Exercise 1: 3 possible interpretions in the form of parse trees

- She made an announcement of a program. The announcement promoted safety in trucks and vans.

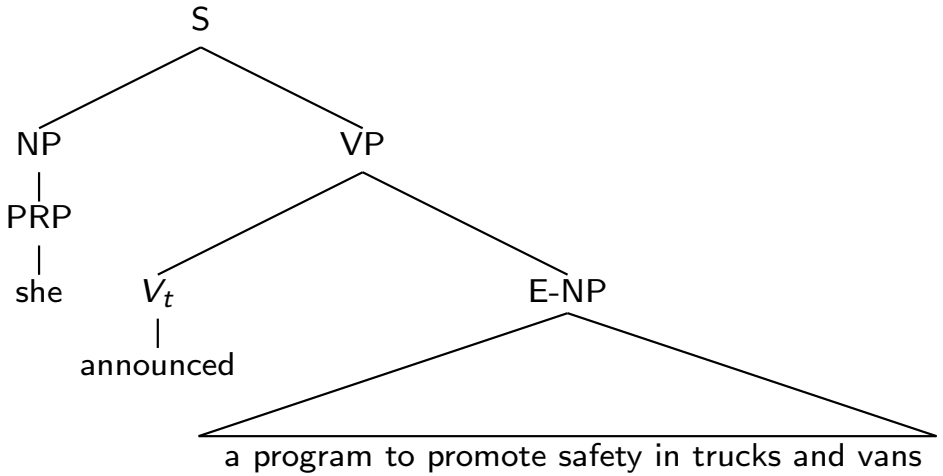


# Exercise 1: 3 possible interpretions in the form of parse trees

- She made an announcement of a program. The announcement promoted safety. The announcement was in trucks and vans.



# Exercise 1: a CFG to get the first interpretation



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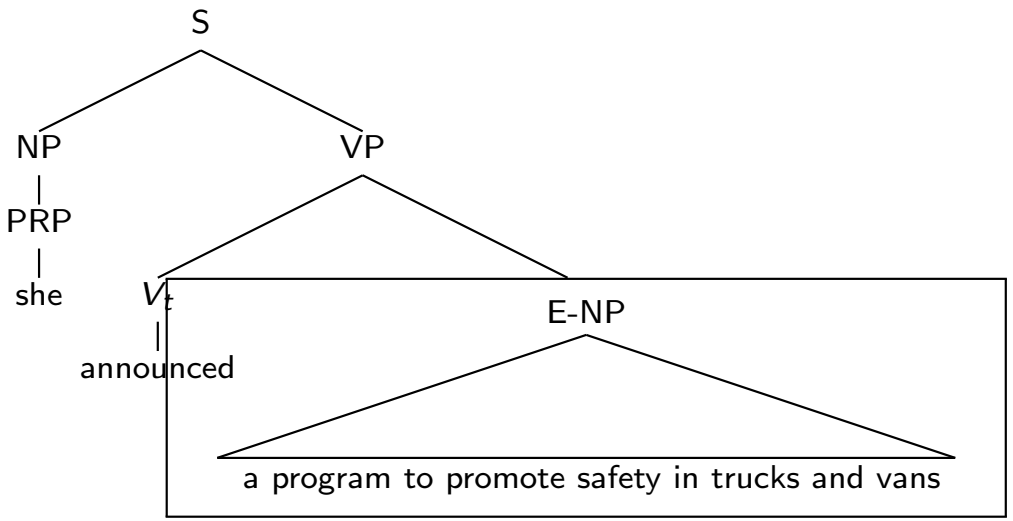

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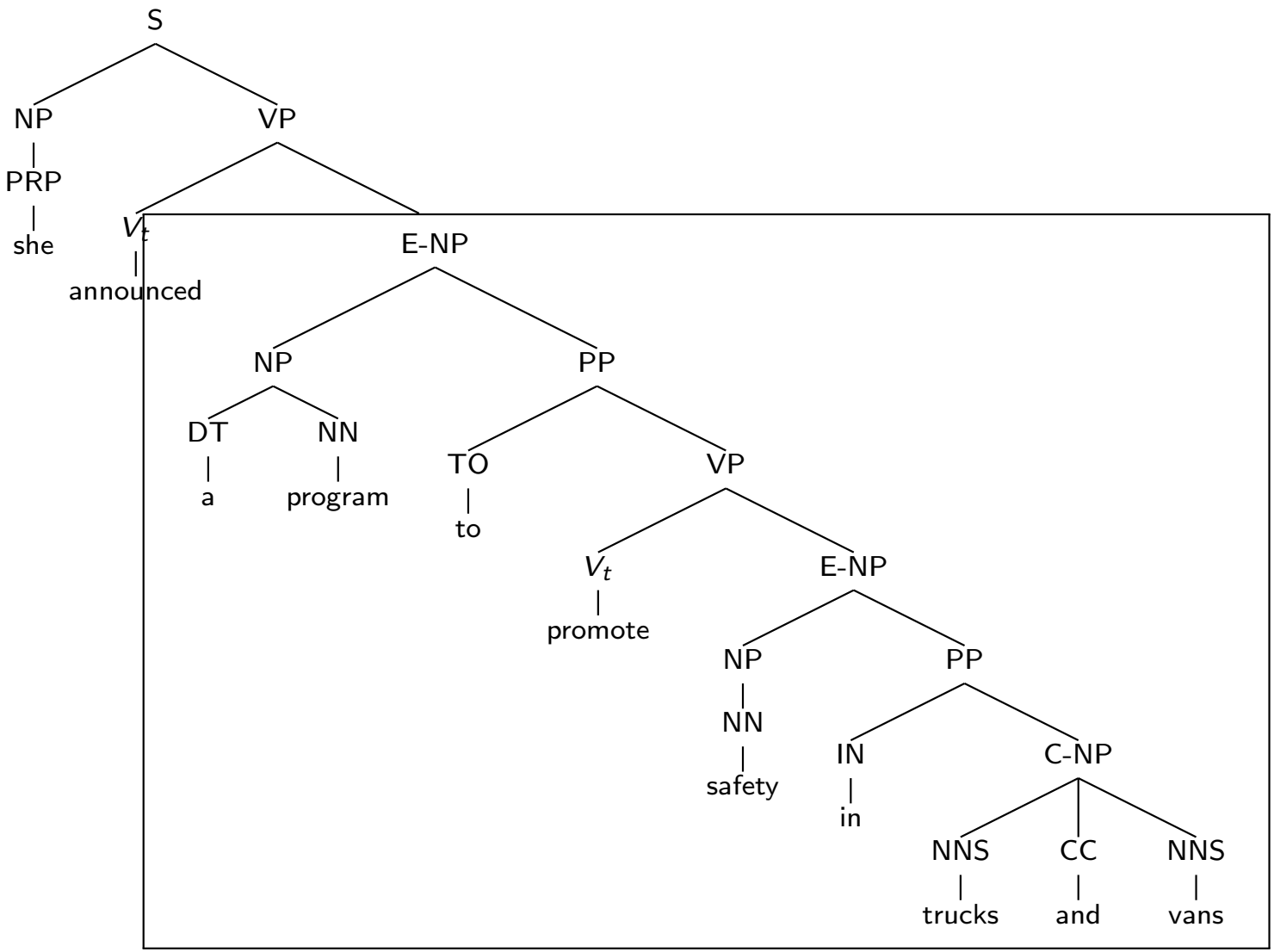

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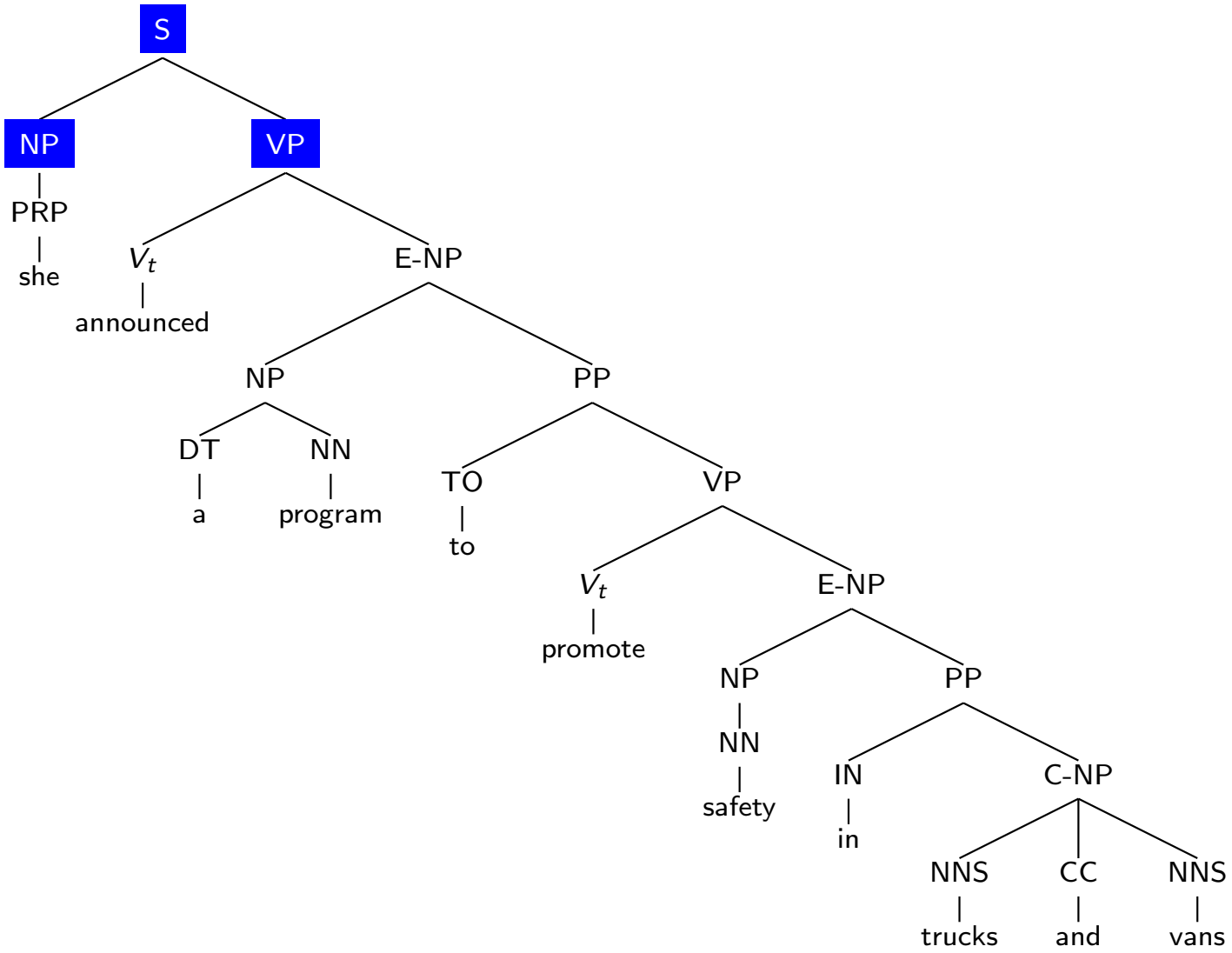
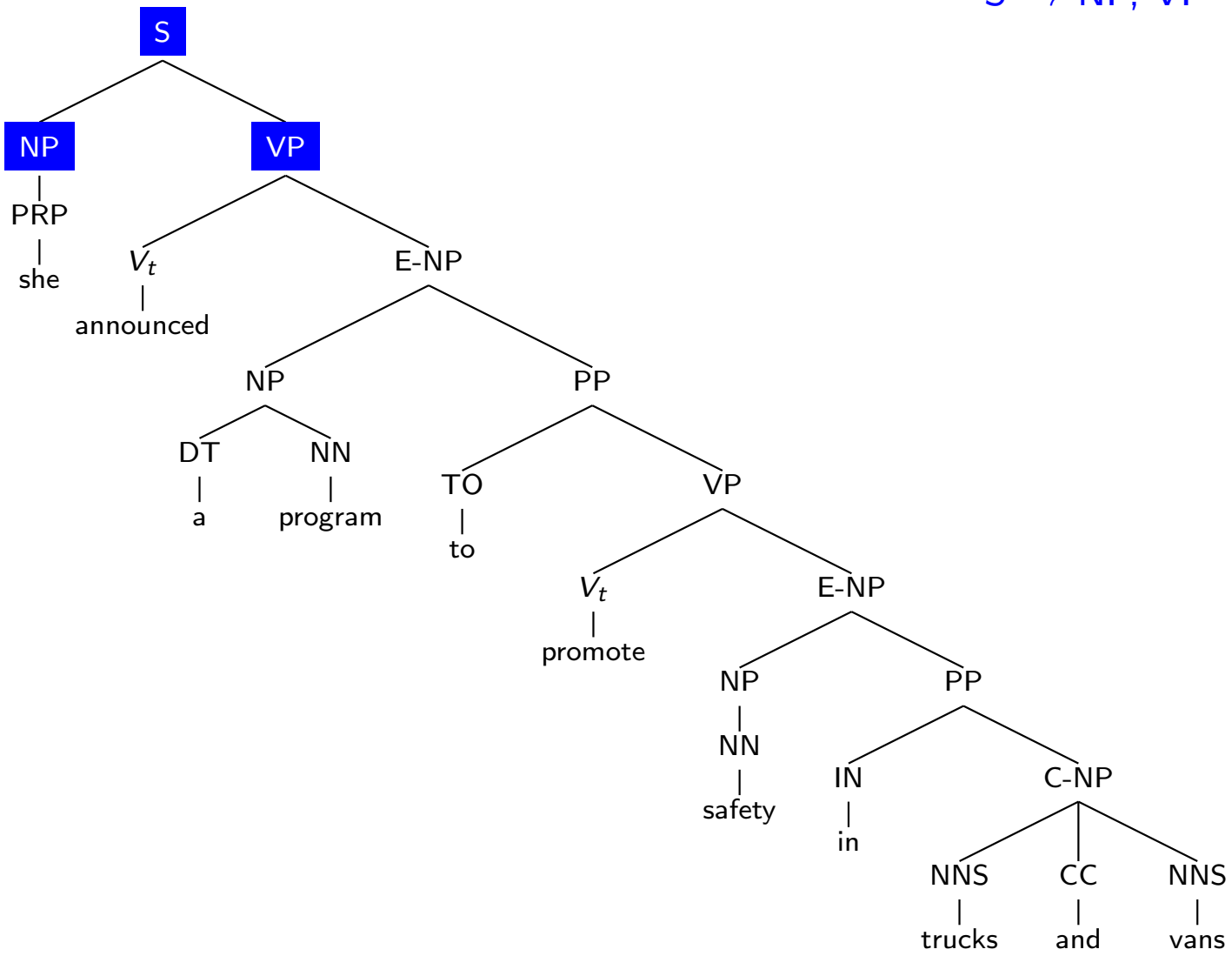


# Exercise 1: a CFG to get the first interpretation

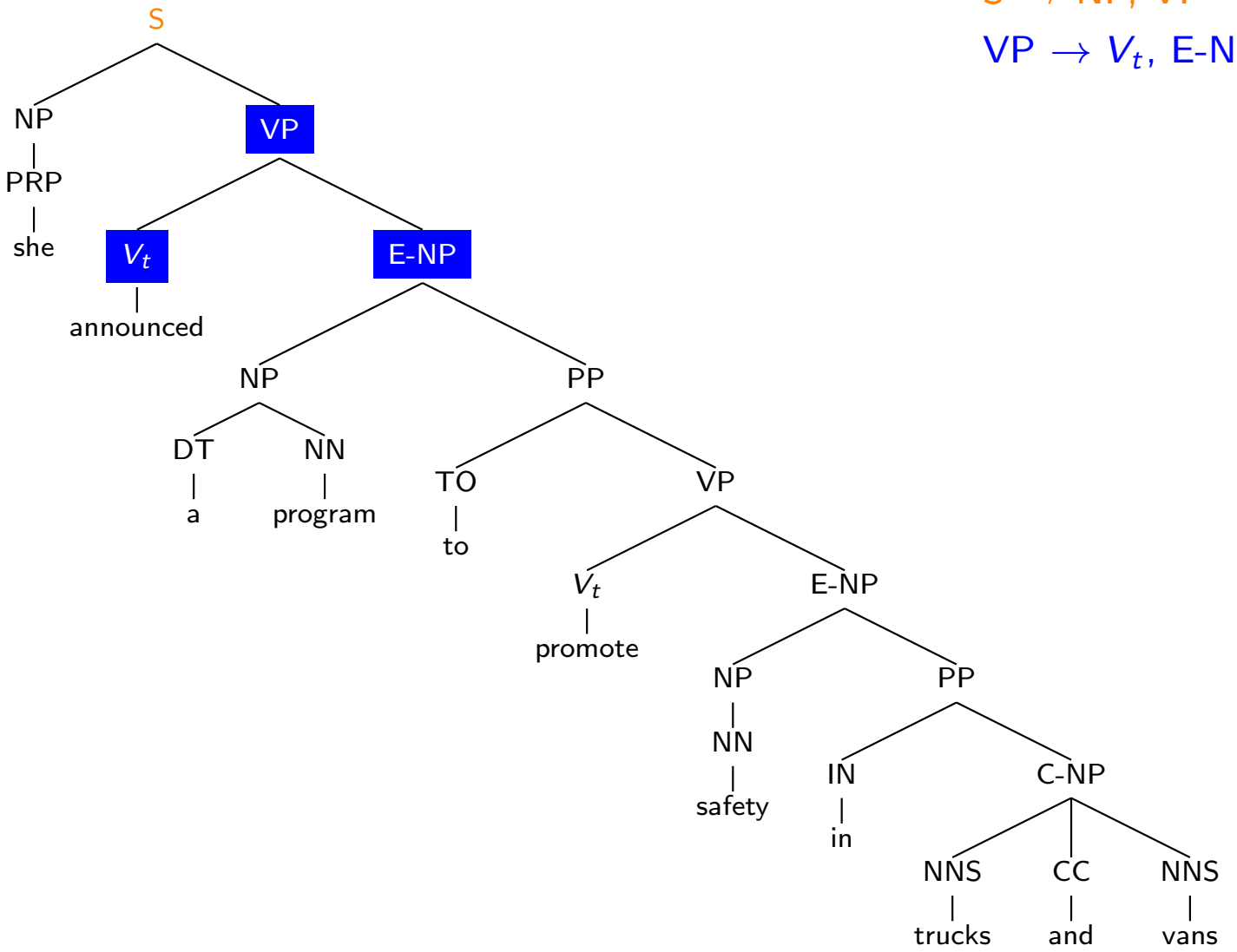
$S \rightarrow NP, VP$



# Exercise 1: a CFG to get the first interpretation

$S \rightarrow NP, VP$

$VP \rightarrow V_t, E\text{-}NP$



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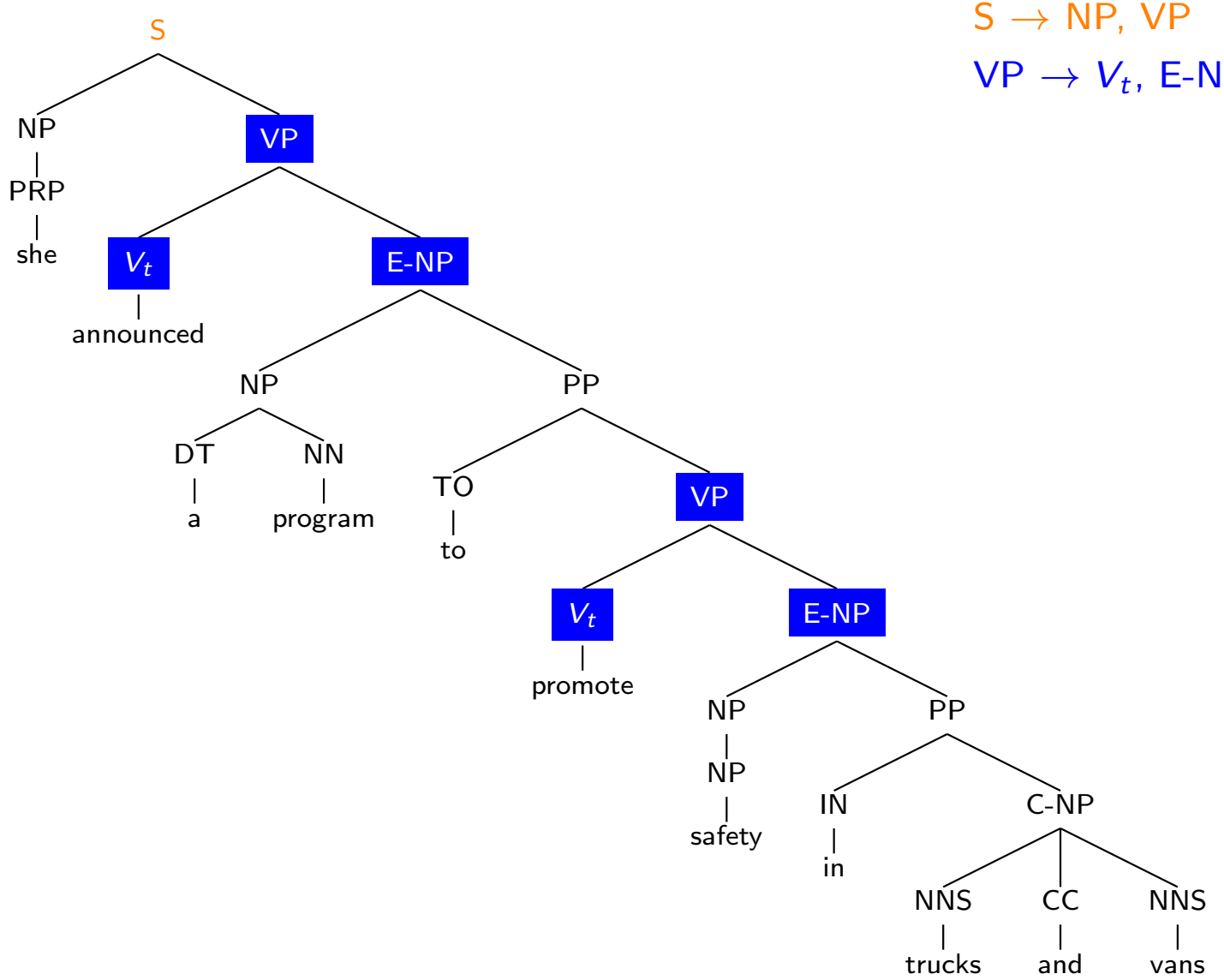

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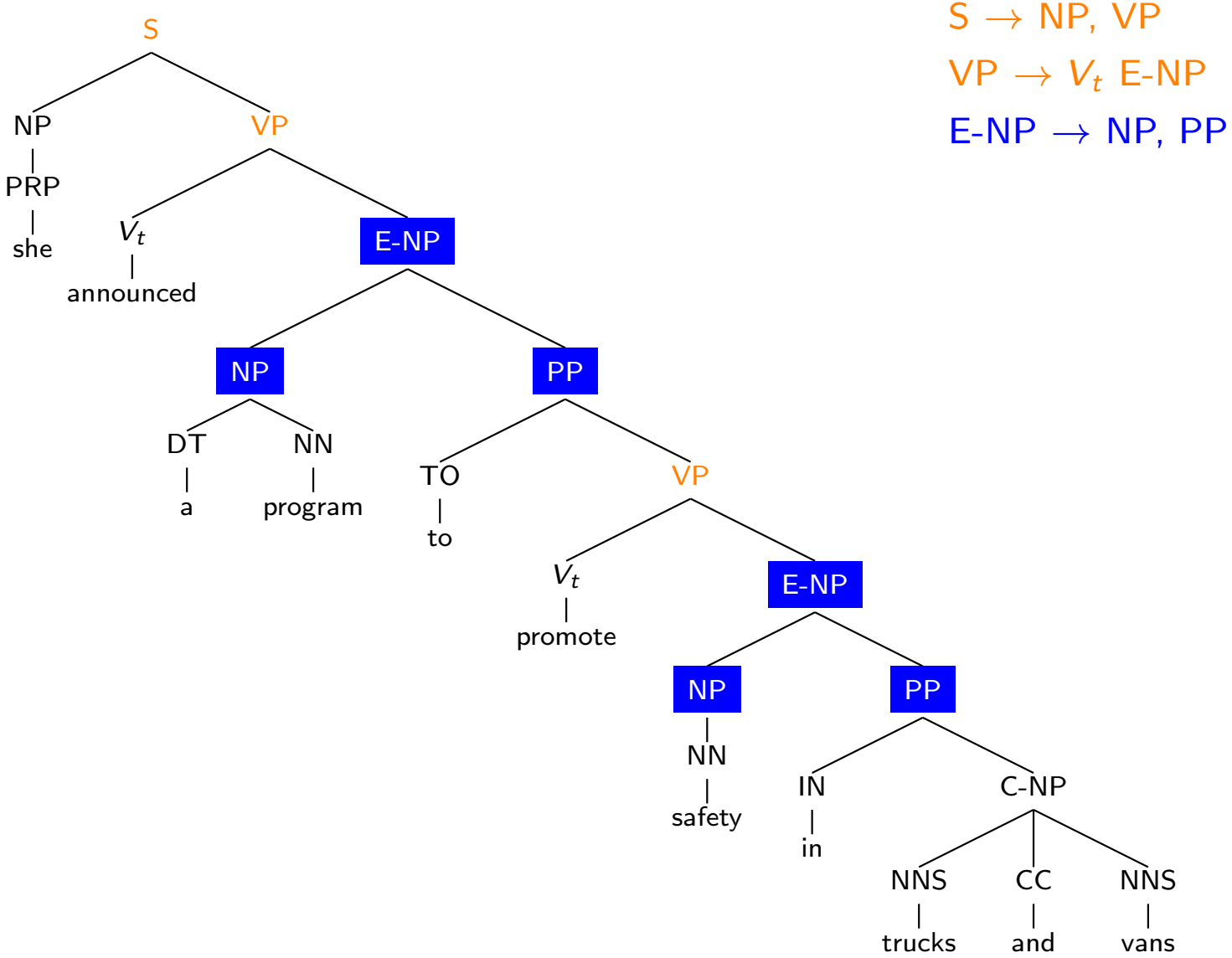
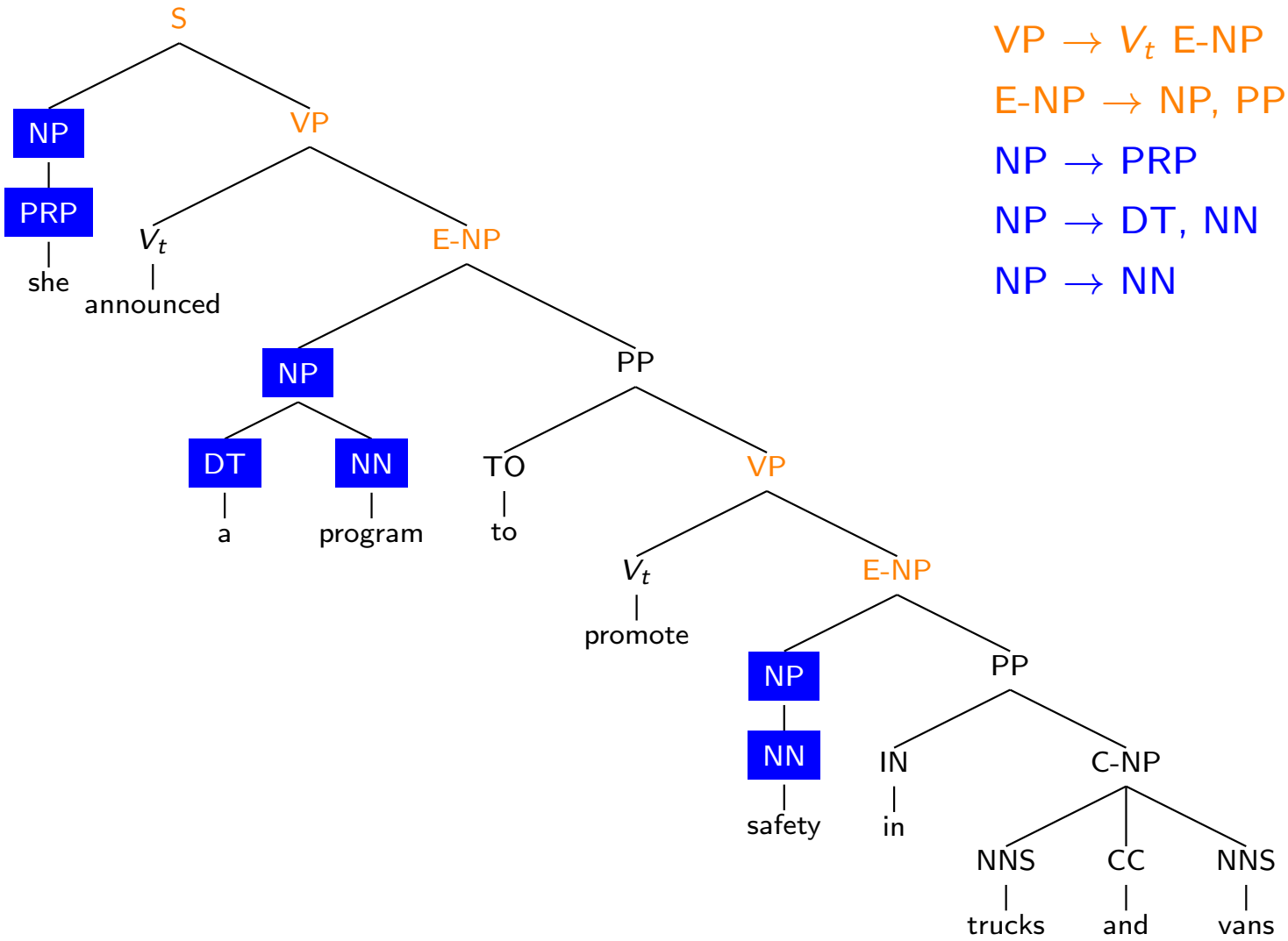



$S \rightarrow NP, VP$

$VP \rightarrow V_t$ E-NP

E-NP $\rightarrow$ NP, PP

# Exercise 1: a CFG to get the first interpretation




$S \rightarrow NP, VP$

$VP \rightarrow V_t$ E-NP

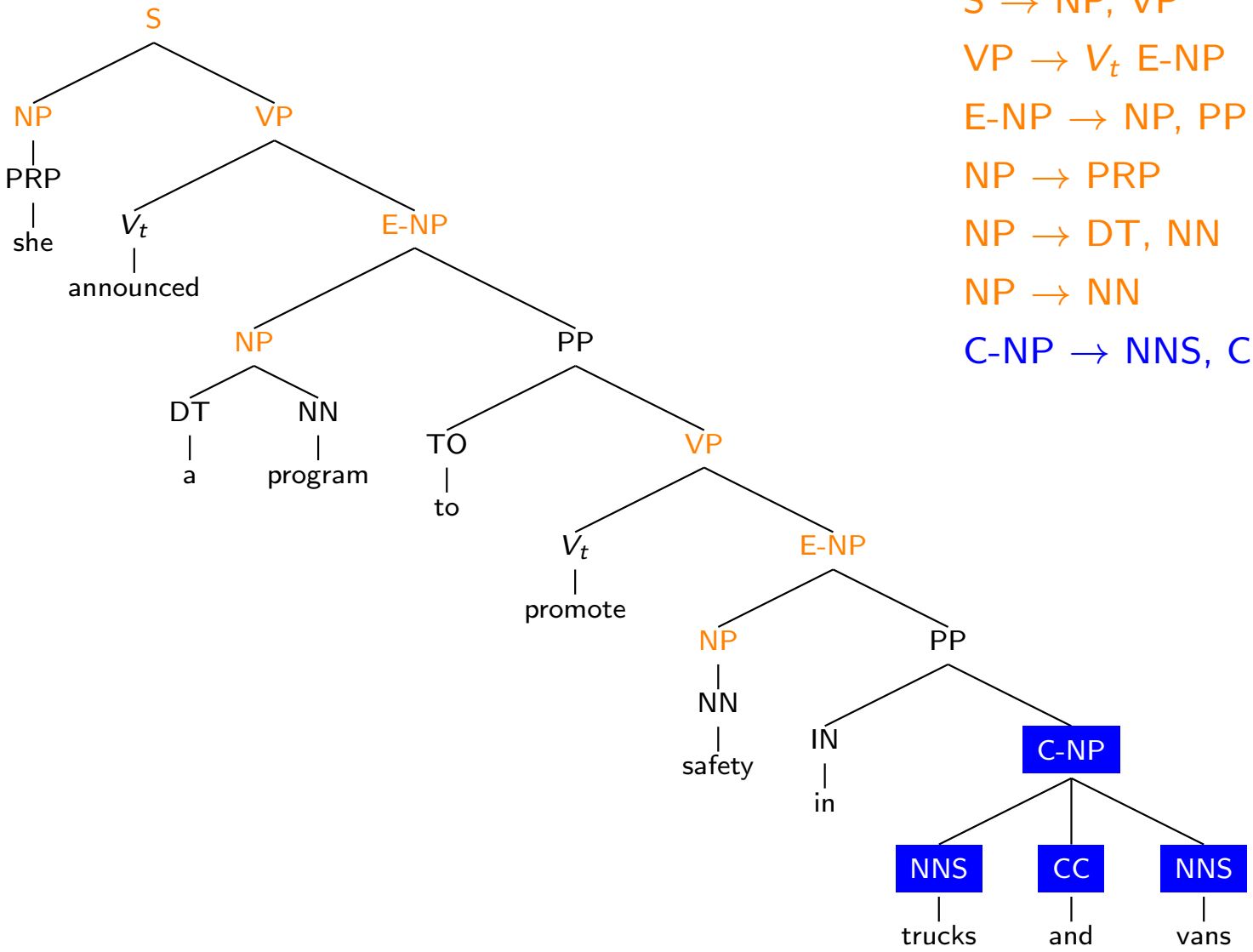
E-NP $\rightarrow$ NP, PP

$NP \rightarrow PRP$

$NP \rightarrow DT, NN$

$NP \rightarrow NN$

# Exercise 1: a CFG to get the first interpretation




S → NP, VP

VP → $V_t$ E-NP

E-NP → NP, PP

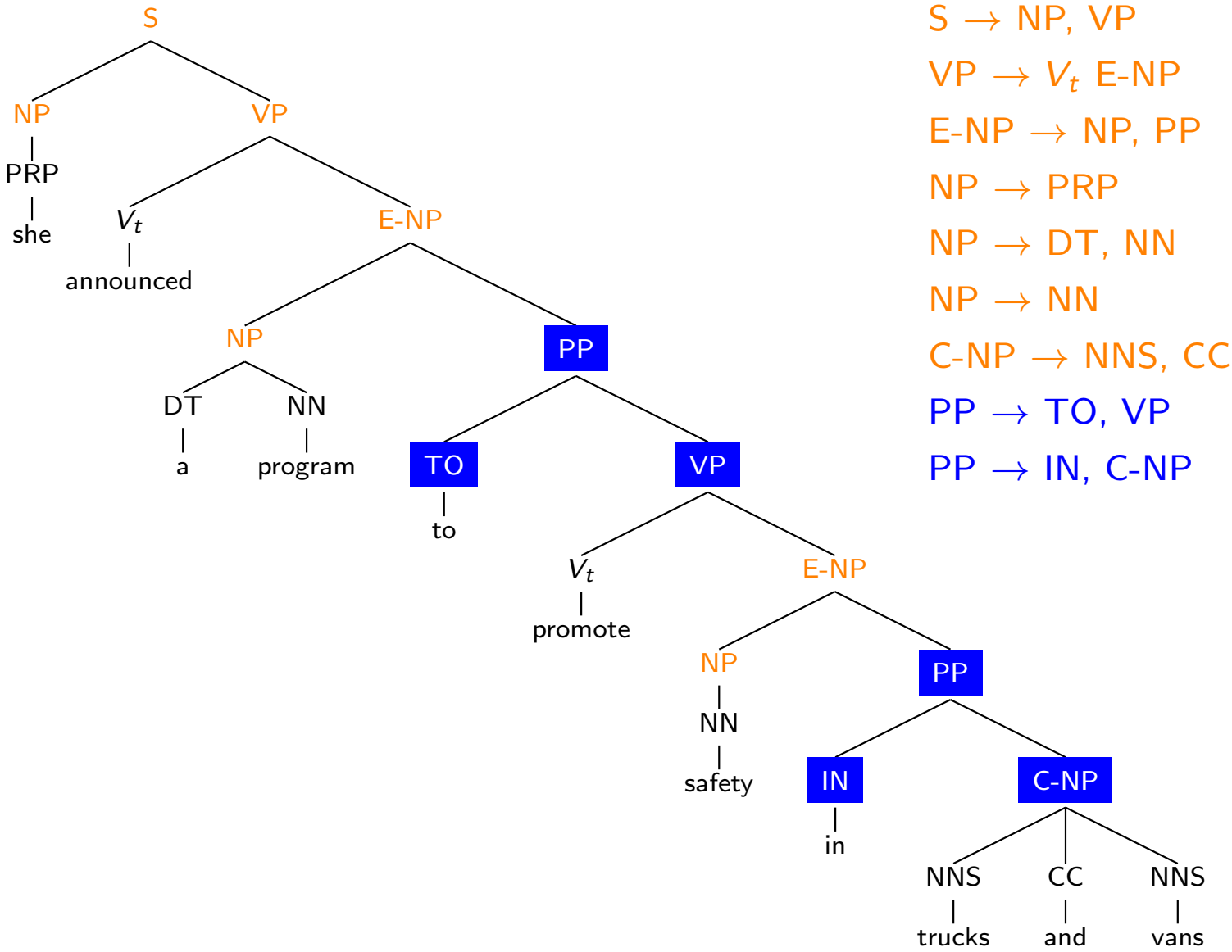
NP → PRP

NP → DT, NN

NP → NN

C-NP → NNS, CC, NNS

# Exercise 1: a CFG to get the first interpretation




S → NP, VP

VP → $V_t$ E-NP

E-NP → NP, PP

NP → PRP

NP → DT, NN

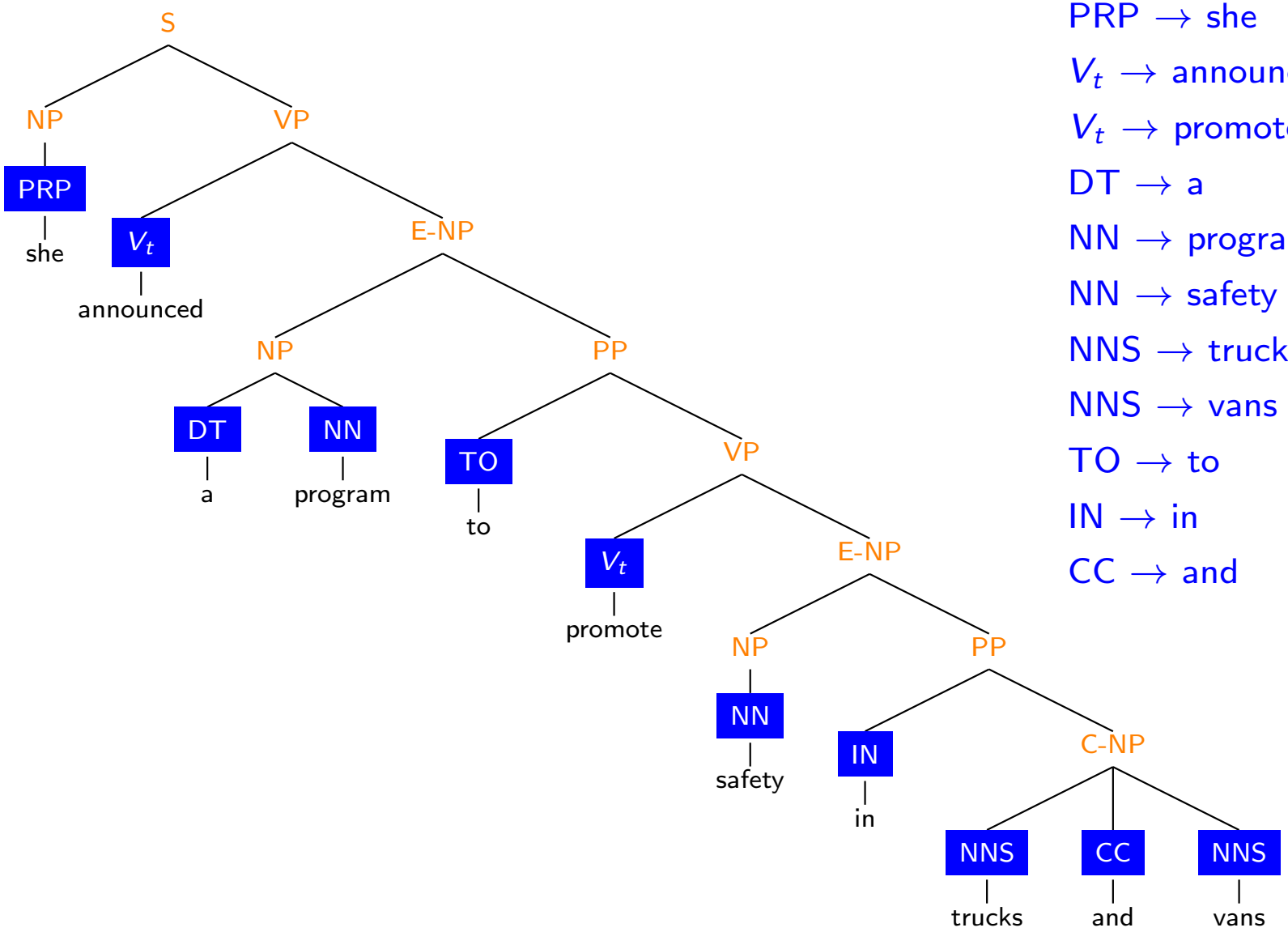
NP → NN

C-NP → NNS, CC, NNS

PP → TO, VP

PP → IN, C-NP

# Exercise 1: a CFG to get the first interpretation




PRP $\rightarrow$ she

$V_t \rightarrow$ announced

$V_t \rightarrow$ promote

DT $\rightarrow$ a

NN $\rightarrow$ program

NN $\rightarrow$ safety

NNS $\rightarrow$ trucks

NNS $\rightarrow$ vans

TO $\rightarrow$ to

IN $\rightarrow$ in

CC $\rightarrow$ and

# Exercise 1: a CFG to get the first interpretation

## CFG Format 1

S → NP, VP

VP → $V_t$, E-NP

E-NP → NP, PP

NP → PRP

NP → DT, NN

NP → NN

C-NP → NNS, CC, NNS

PP → TO, VP

PP → IN, C-NP

PRP → she

$V_t$ → announced

$V_t$ → promote

DT → a

NN → program

NN → safety

NNS → trucks

NNS → vans

TO → to

IN → in

CC → and

## CFG format 2

S → NP, VP

VP → $V_t$, E-NP

E-NP → NP, PP

NP → PRP | DT, NN | NN

C-NP → NNS, CC, NNS

PP → TO, VP | IN, C-NP

PRP → she

$V_t$ → announced | promote

DT → a

NN → program | safety

NNS → trucks | vans

TO → to

IN → in

CC → and

# Exercise 2

Using the following PCFG

| | |
|---|---|
| $S \rightarrow NP\ VP$ | 1.0 |
| $NP \rightarrow NP\ PP$ | 0.4 |
| $PP \rightarrow P\ NP$ | 1.0 |
| $VP \rightarrow V\ NP$ | 0.7 |
| $VP \rightarrow VP\ PP$ | 0.3 |
| $P \rightarrow with$ | 1.0 |
| $V \rightarrow saw$ | 1.0 |
| $NP \rightarrow astronomers$ | 0.1 |
| $NP \rightarrow ears$ | 0.18 |
| $NP \rightarrow saw$ | 0.04 |
| $NP \rightarrow stars$ | 0.18 |
| $NP \rightarrow telescope$ | 0.1 |

Work with the sentence: *'astronomers saw stars with ears'*

a) How many correct parses are there for this sentence?

b) Write them along with their probabilities.

# Exercise 2: How many correct parses for that sentence?

| | |
|---|---|
| $S \rightarrow NP\ VP$ | 1.0 |
| $NP \rightarrow NP\ PP$ | 0.4 |
| $PP \rightarrow P\ NP$ | 1.0 |
| $VP \rightarrow V\ NP$ | 0.7 |
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Two parses given the ambiguity introduced by the rules VP:

# Exercise 2: How many correct parses for that sentence?

| | |
|---|---|
| $S \rightarrow NP\ VP$ | 1.0 |
| $NP \rightarrow NP\ PP$ | 0.4 |
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Two parses given the ambiguity introduced by the rules VP:

- VP $\rightarrow$ V, NP

  Astronomers saw stars and the starts have ears.

  V = 'saw' + NP= NP ('stars'), PP ('with ears')

# Exercise 2: How many correct parses for that sentence?

| | |
|---|---|
| $S \rightarrow NP\ VP$ | 1.0 |
| $NP \rightarrow NP\ PP$ | 0.4 |
| $PP \rightarrow P\ NP$ | 1.0 |
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Two parses given the ambiguity introduced by the rules VP:

- VP $\rightarrow$ V, NP

  Astronomers saw stars and the starts have ears.

  V = 'saw' + NP= NP ('stars'), PP ('with ears')

- VP $\rightarrow$ VP, PP

  Astronomers saw stars using their ears.

  VP = V ('saw'), NP ('stars') + PP= P ('with'), NP ('ears')

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

| | |
|---|---|
| $S \rightarrow NP\ VP$ | 1.0 |
| $NP \rightarrow NP\ PP$ | 0.4 |
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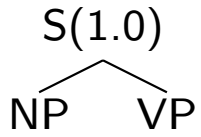


$P(T) = P(S \rightarrow NP\ VP)$

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

| | |
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| $S \rightarrow NP\ VP$ | 1.0 |
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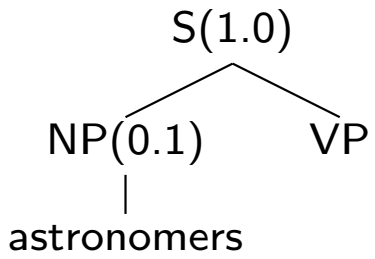


$P(T) = P(S \rightarrow NP\ VP)\ P(NP \rightarrow astronomers)$

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

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|---|---|
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| $NP \rightarrow NP\ PP$ | 0.4 |
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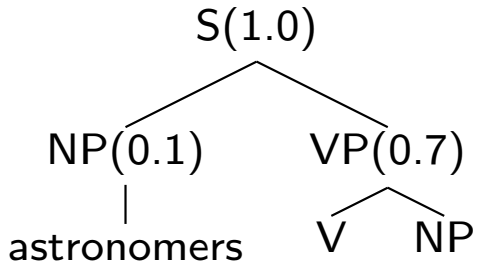


$P(T) = P(S \rightarrow NP\ VP)\ P(NP \rightarrow astronomers)\ P(VP \rightarrow V\ NP)$

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

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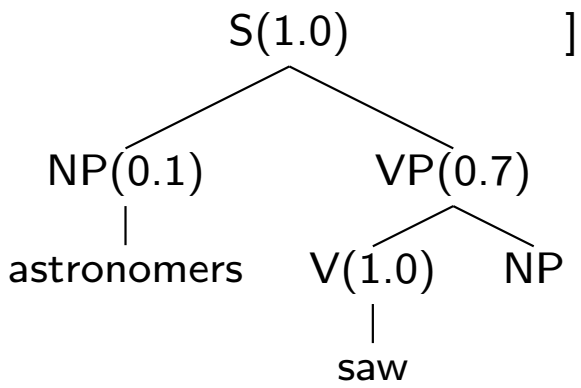


$$P(T) = P(S \rightarrow NP\ VP)\ P(NP \rightarrow astronomers)\ P(VP \rightarrow V\ NP)\ P(V \rightarrow saw)$$

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

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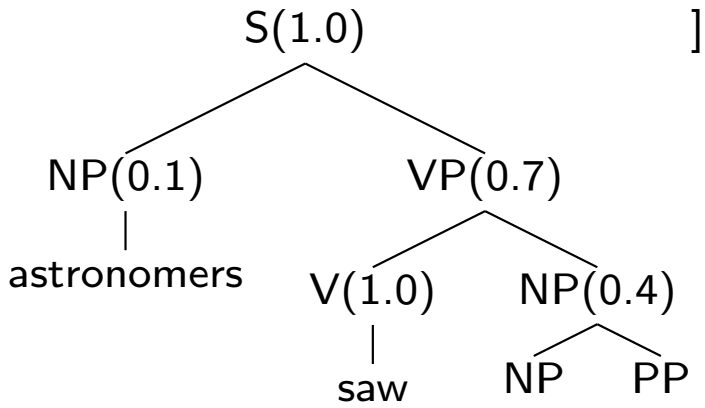


$$P(T) = P(S \rightarrow NP\ VP)\ P(NP \rightarrow astronomers)\ P(VP \rightarrow V\ NP)\ P(V \rightarrow saw)\ P(NP \rightarrow NP\ PP)$$

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

| | |
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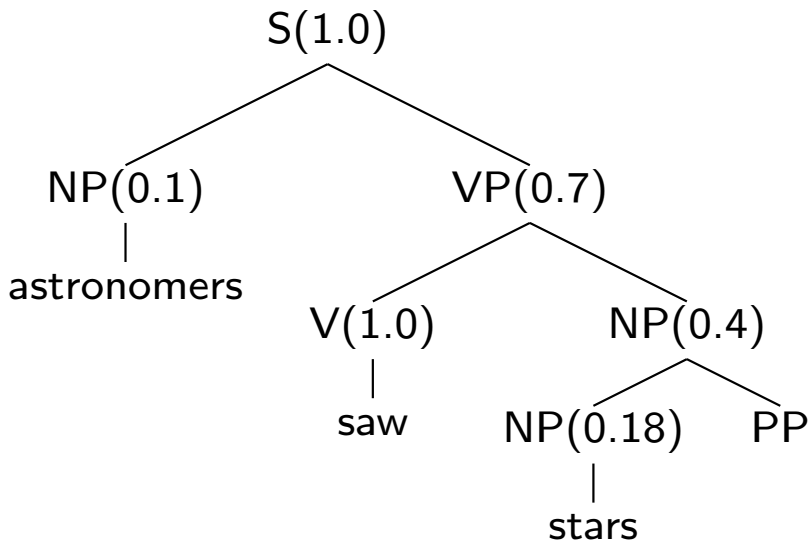


$P(T) = P(S \rightarrow NP\ VP)\ P(NP \rightarrow astronomers)\ P(VP \rightarrow V\ NP)\ P(V \rightarrow saw)\ P(NP \rightarrow NP\ PP)\ P(NP \rightarrow stars)$

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

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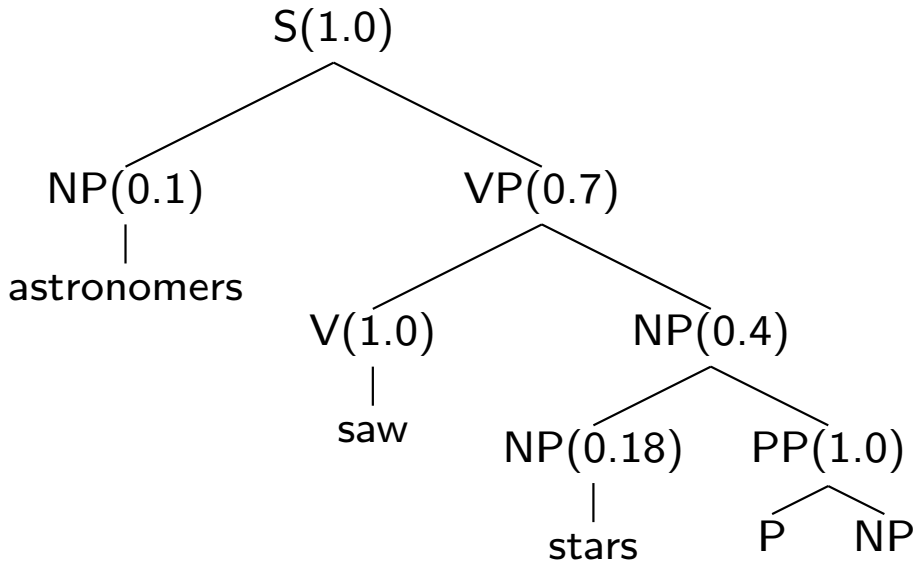


$P(T) = P(S \rightarrow NP\ VP)\ P(NP \rightarrow astronomers)\ P(VP \rightarrow V\ NP)\ P(V \rightarrow saw)\ P(NP \rightarrow NP\ PP)\ P(NP \rightarrow stars)\ P(PP \rightarrow P\ NP)$

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

| | |
|---|---|
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| $NP \rightarrow NP\ PP$ | 0.4 |
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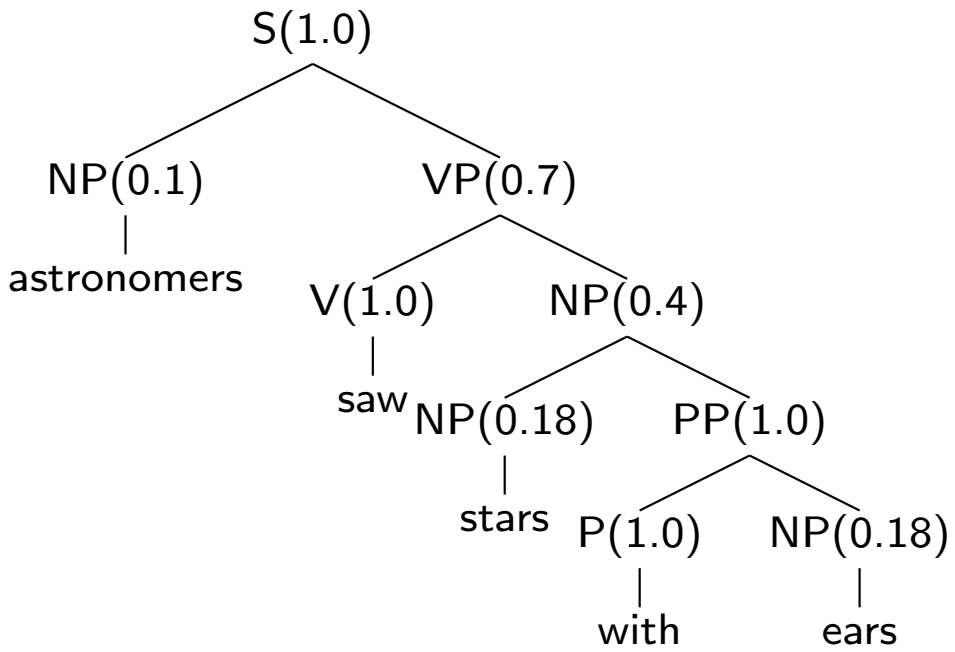


$P(T) = P(S \rightarrow NP\ VP)\ P(NP \rightarrow astronomers)\ P(VP \rightarrow V\ NP)\ P(V \rightarrow saw)\ P(NP \rightarrow NP\ PP)\ P(NP \rightarrow stars)\ P(PP \rightarrow P\ NP)\ P(P \rightarrow with)\ P(NP \rightarrow ears)$

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

| | |
|---|---|
| $S \rightarrow NP\ VP$ | 1.0 |
| $NP \rightarrow NP\ PP$ | 0.4 |
| $PP \rightarrow P\ NP$ | 1.0 |
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| $V \rightarrow saw$ | 1.0 |
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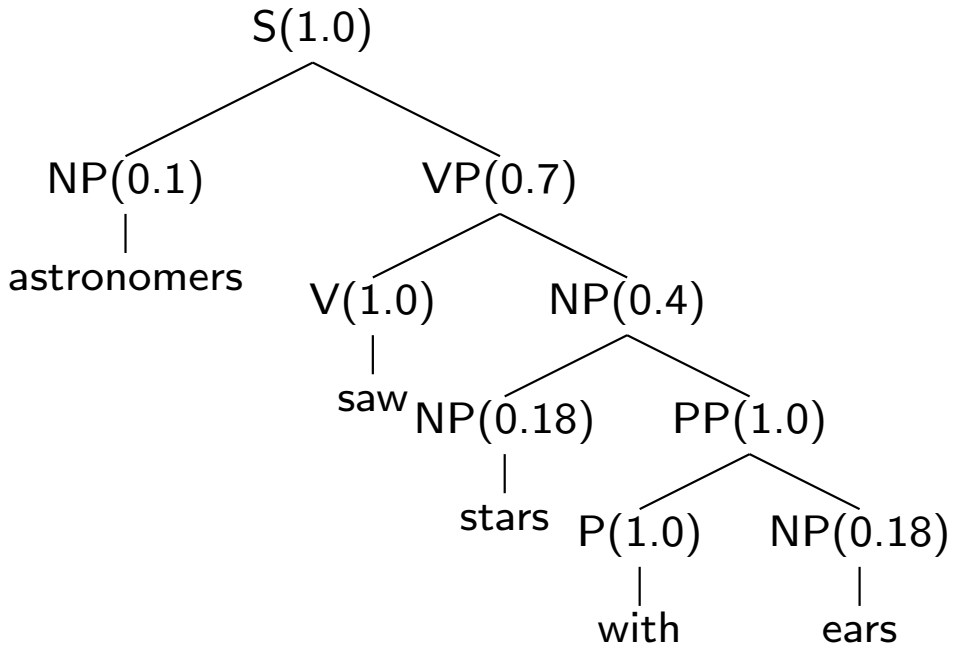


$P(T) = P(S \rightarrow NP\ VP)\ P(NP \rightarrow astronomers)\ P(VP \rightarrow V\ NP)\ P(V \rightarrow saw)\ P(NP \rightarrow NP\ PP)\ P(NP \rightarrow stars)\ P(PP \rightarrow P\ NP)\ P(P \rightarrow with)\ P(NP \rightarrow ears)$

$P(T) = 0.0009072$

# Exercise 2: write the correct probabilistic parse trees

*'astronomers saw stars with ears'*

| | |
|---|---|
| $S \rightarrow NP\ VP$ | 1.0 |
| $NP \rightarrow NP\ PP$ | 0.4 |
| $PP \rightarrow P\ NP$ | 1.0 |
| $VP \rightarrow V\ NP$ | 0.7 |
| $VP \rightarrow VP\ PP$ | 0.3 |
| $P \rightarrow with$ | 1.0 |
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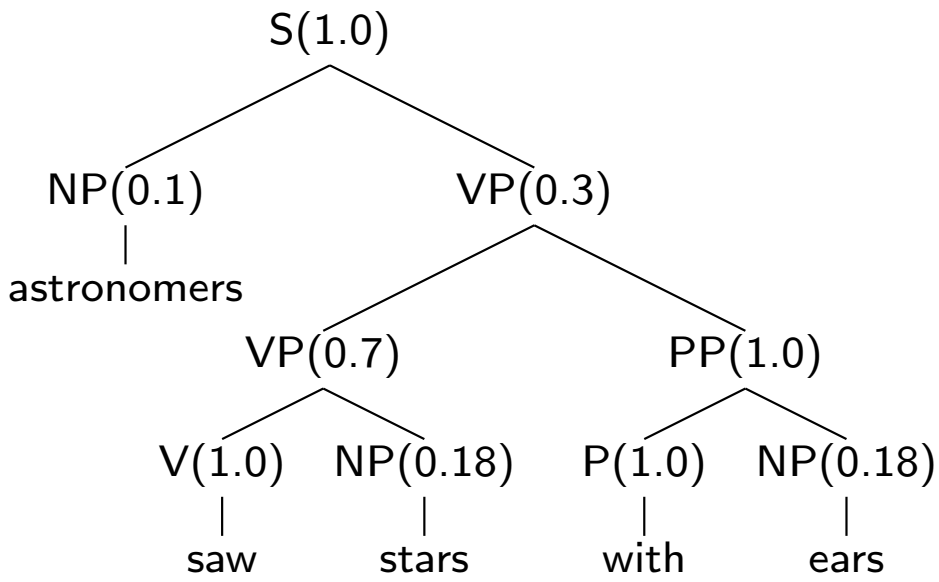


$P(T) = P(S \rightarrow NP\ VP)\ P(NP \rightarrow astronomers)\ P(VP \rightarrow VP\ PP)\ P(VP \rightarrow VP\ NP)\ P(V \rightarrow saw)\ P(NP \rightarrow stars)\ P(PP \rightarrow P\ NP)\ P(P \rightarrow with)\ P(NP \rightarrow ears)$

$P(T) = 0.0006804$