### CKY Parsing

LING 571 — Deep Processing Techniques for NLP October 7, 2019 Shane Steinert-Threlkeld

(h/t Ryan Georgi)



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### Announcements

- HW1: grades posted
  - In general, we will aim for Monday release of grades.
- Distance students:
  - Let us know in chat if/when audio cuts out.

• Trying one thing today; will try something more drastic if the issues persist.





## Announcements: HW #2

- Due Wednesday, 11:00pm Pacific
- Grammar output format:
  - 1. Terminals quoted (single or double)
  - 2. One production per line
  - Optionally, RHS alternates with vertical bar/pipe character: I
  - 3. Start symbol is first nonterminal encountered in file

tical bar/pipe character: I

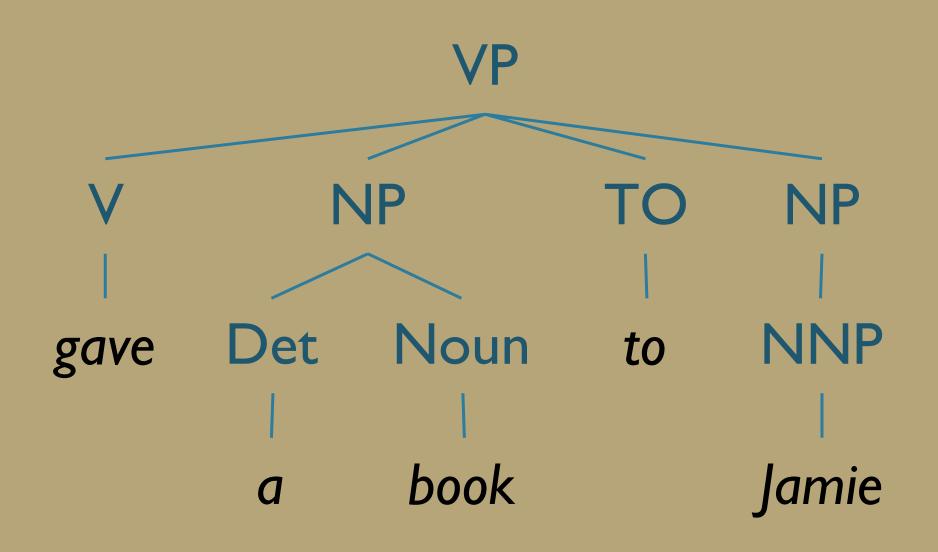




## Variation in CNF: Binarization

### Original Rule

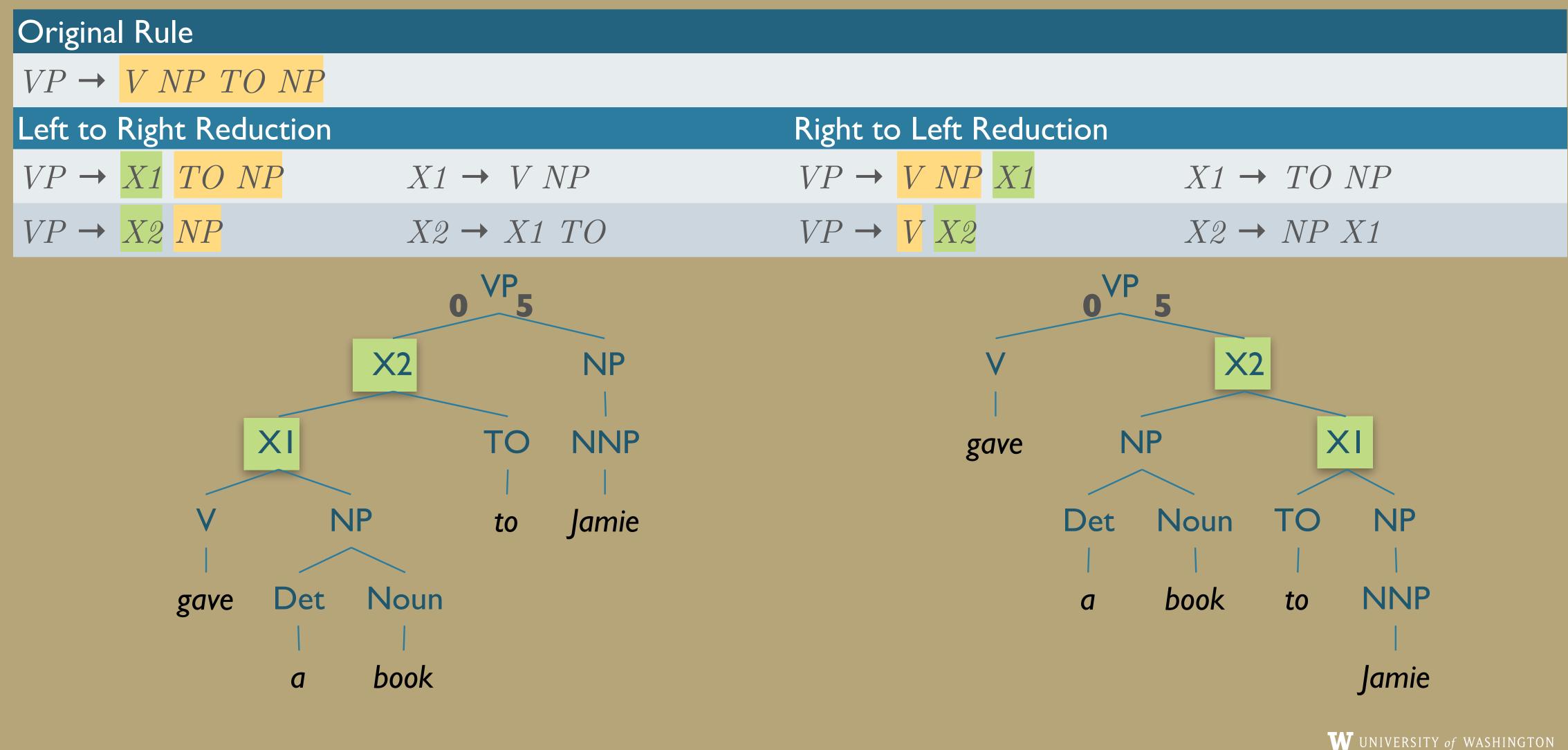
### $VP \rightarrow V NP TO NP$







## Variation in CNF: Binarization







## Roadmap

- CKY Parsing Algorithm
  - Dynamic programming structure
  - Algorithm and example
  - Analysis & Discussion

- Probabilistic CFGs Motivation: Ambiguity
  - Augmenting CFGs with probabilities



### • Given an input string S of length n

- Build table  $(n + 1) \times (n + 1)$ 
  - Indexes correspond to inter-word positions
  - $_0$  Book  $_1$  that  $_2$  flight  $_3$
- Each cell [ i, j ] contains SETS { } of non-terminals with derivations spanning i, j
  - [j-1, j] contains pre-terminals
  - if [0, n] contains the start symbol, the sentence is *accepted*









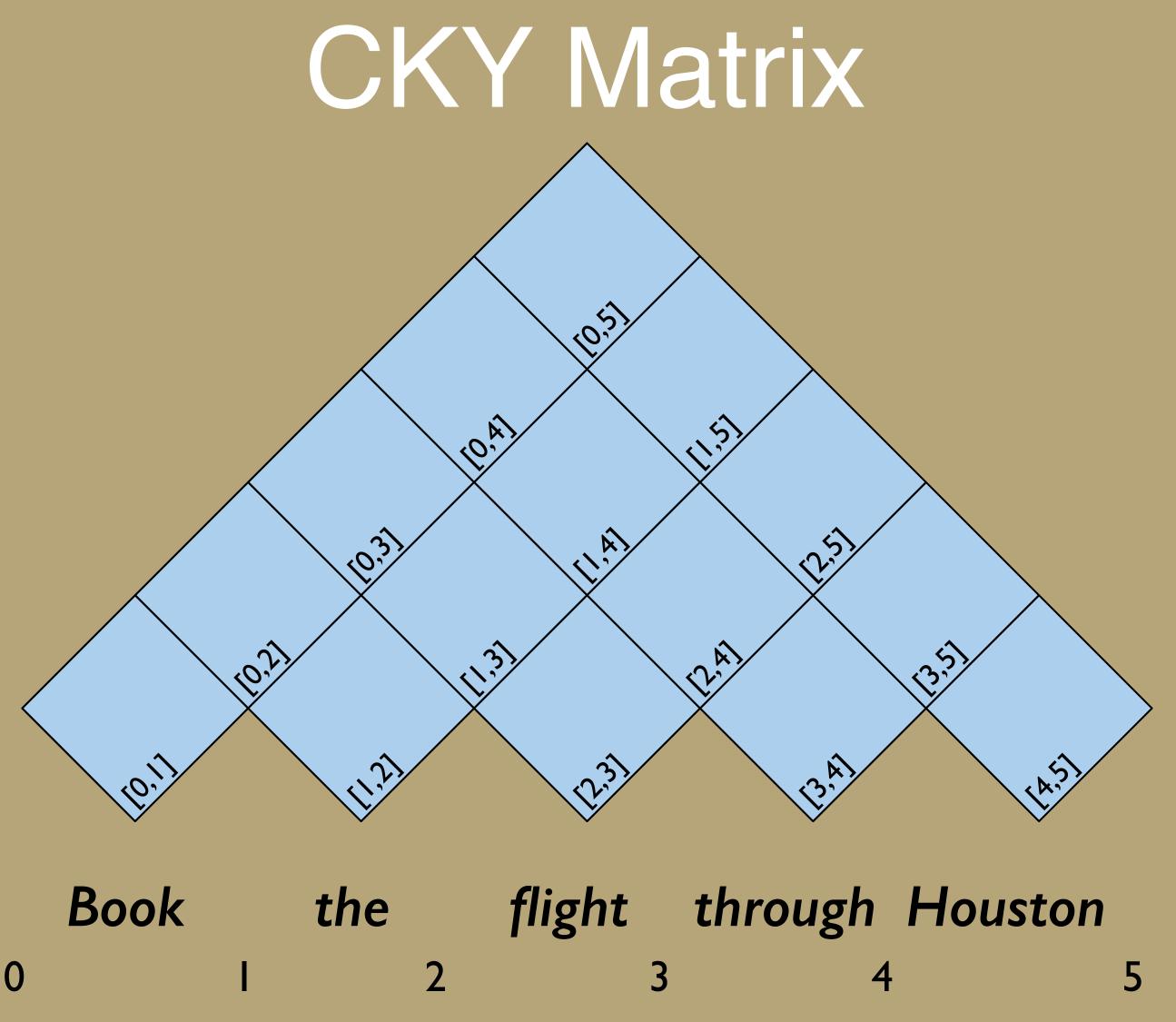




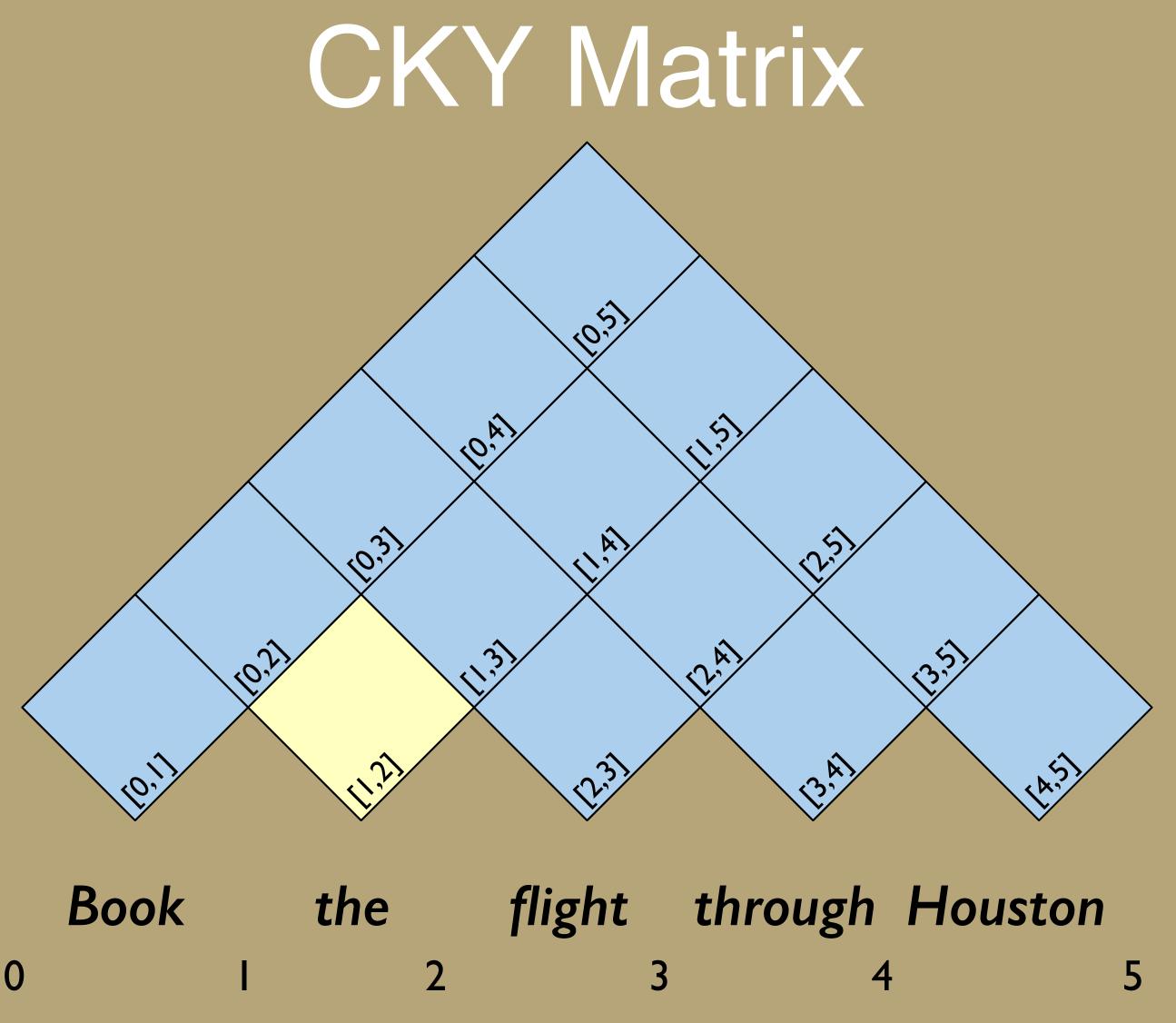
Book	the	flight	through	Houston
[0,1]	[0,2]	[0,3]	[0,4]	[0,5]
	[1,2]	[1,3]	[1,4]	[1,5]
		[2,3]	[2,4]	[2,5]
			[3,4]	[3,5]
				[4,5]

### CKY Matrix

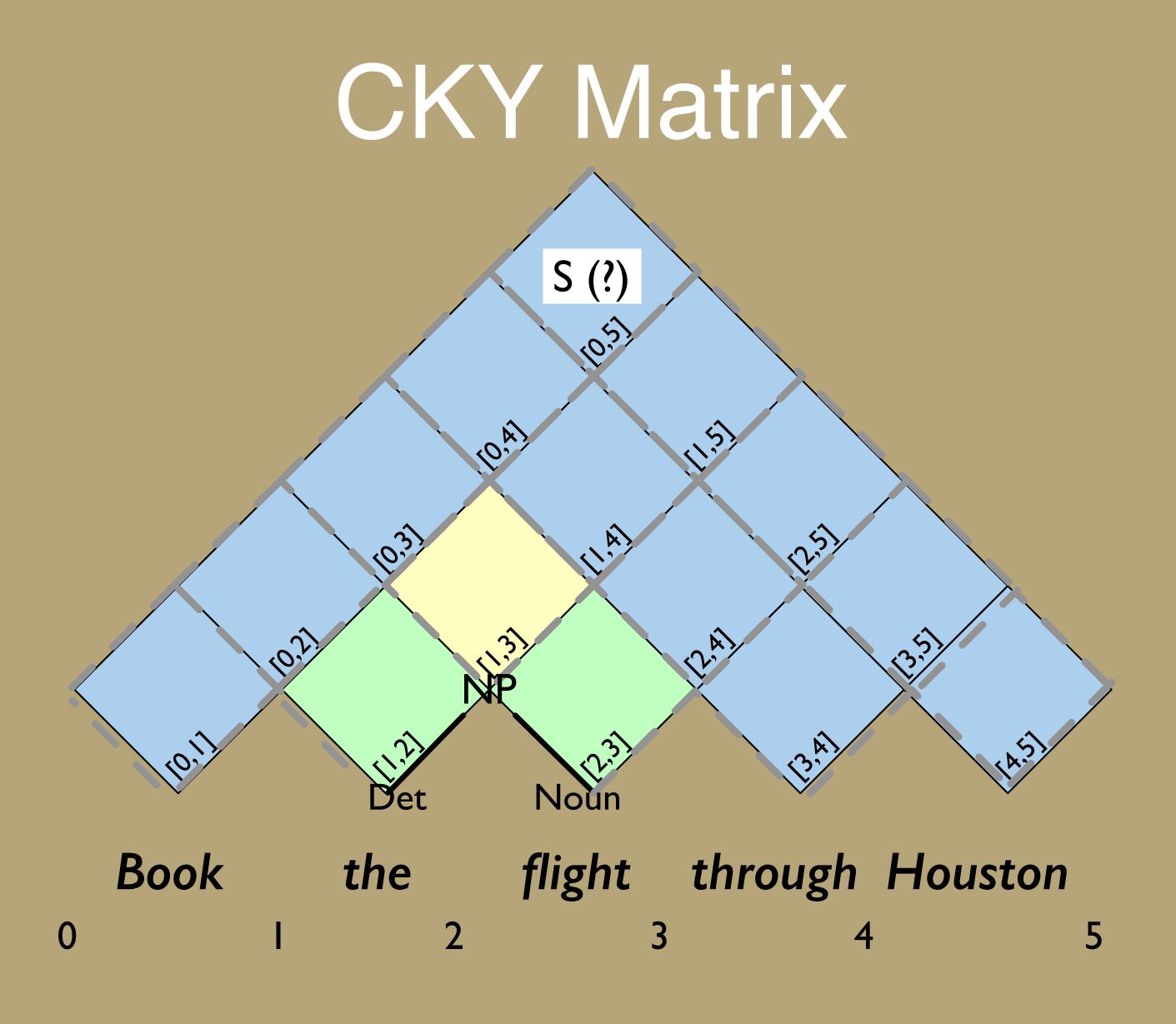












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# Dynamic Programming in CKY

- Key idea:
  - for i < k < j
  - ...and a parse spanning substring [i, j]
  - There is a k such that there are parses spanning [i, k] and [k, j]
  - We can construct parses for whole sentences by building from these partial Ø parses
- So to have a rule  $A \rightarrow B$  C in [i, j]• Must have B in [i, k] and C in [k, j] for some i < k < jCNF forces this for all j > i+1



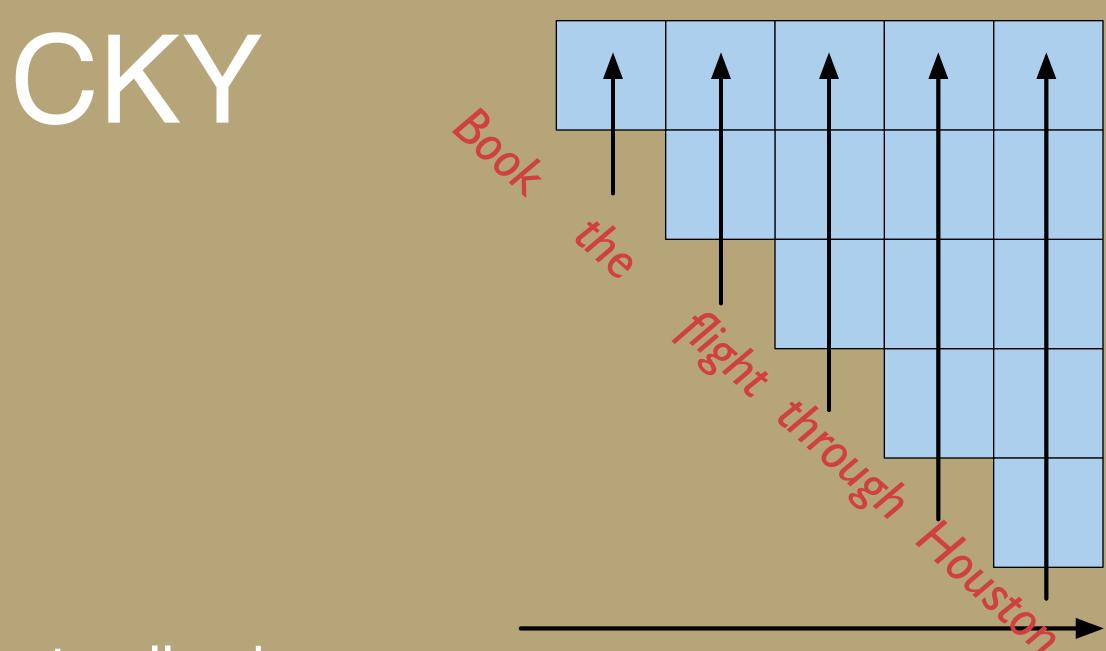


### • Table fills:

- Column-by-column, left-to-right
- bottom-to-top

### • Why?

- To fill each cell, must have access to all sub-spans
- Allows online sentence analysis
  - Works across input string as it arrives



• For cell [ i, j], must be able to access all cells [i, k] and [ k, j] where i < k < j





## CKY Algorithm

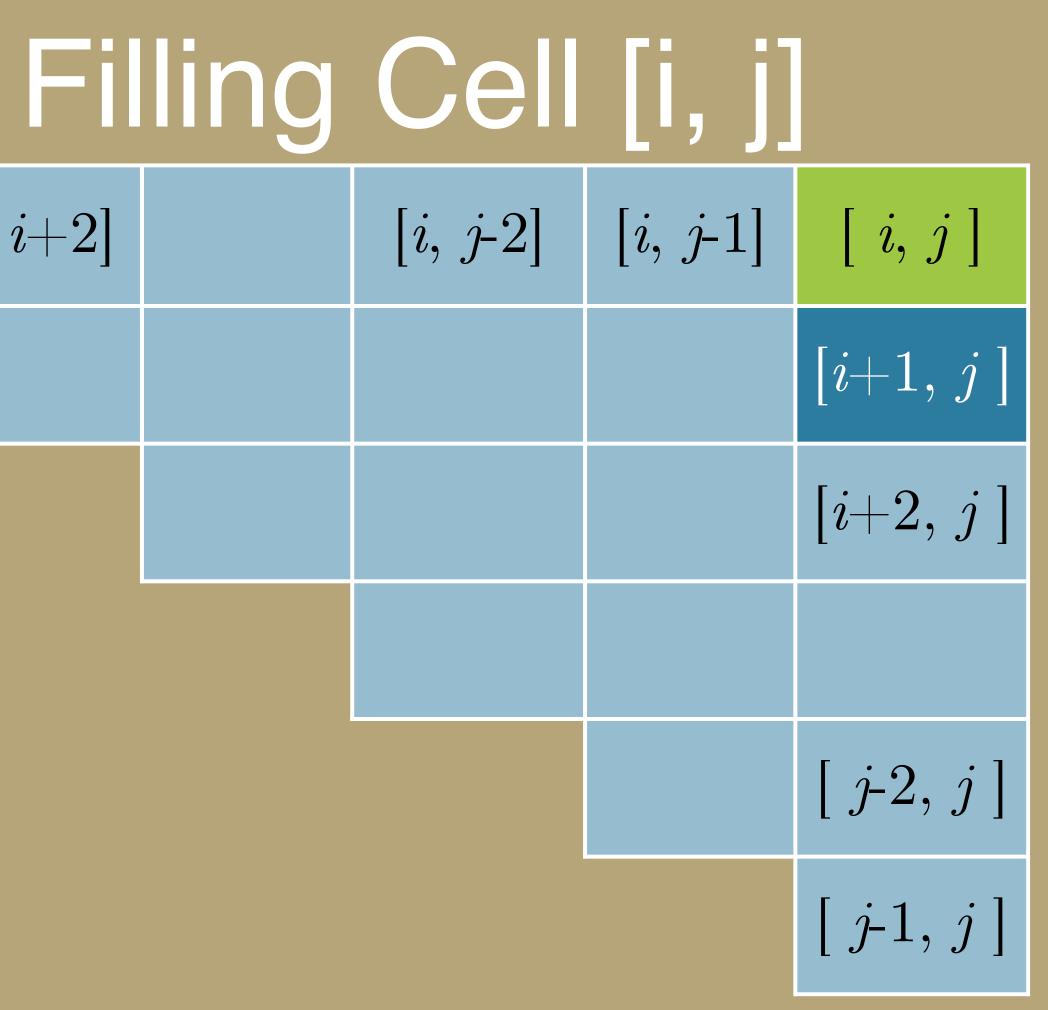
function CKY-PARSE(words, grammar) returns table for  $j \leftarrow from 1$  to LENGTH(words) do  $table[j-1, j] \leftarrow \{A \mid A \rightarrow words[j] \in grammar\}$ for  $i \leftarrow \text{from } j - 2 \text{ downto } 0 \text{ do}$ for  $k \leftarrow i + 1$  to j - 1 do  $table[i, j] \leftarrow table[i, j] \cup$  $\{A \mid A \rightarrow BC \in grammar\}$  $B \in table[i, k],$  $C \in table[k, j]$ 

- Left-to-right, bottom-to-top

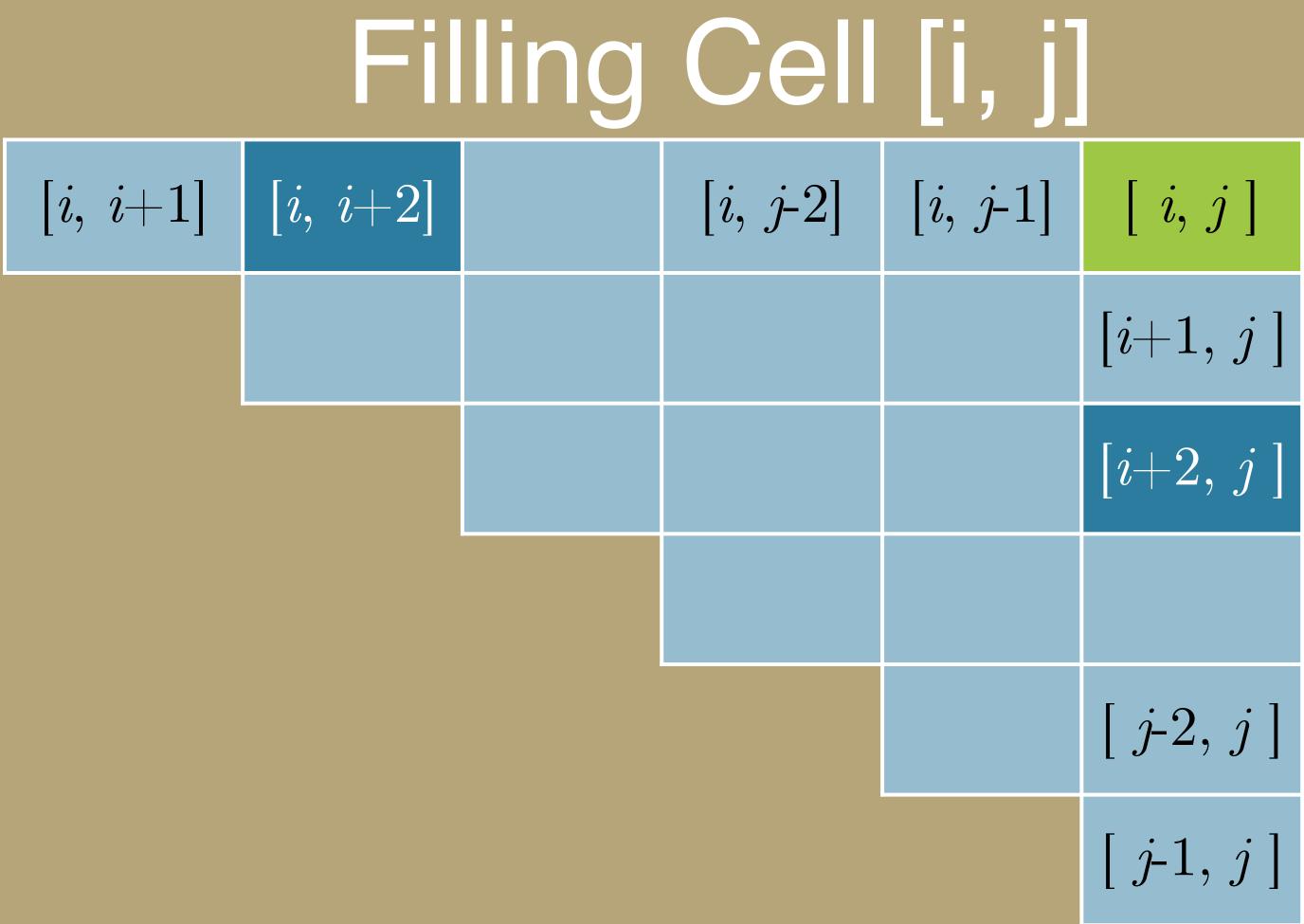
 Sliding k as the pivot for child nodes • Filling the cell with set of applicable rules



$$[i, i+1]$$
  $[i, i+2]$ 

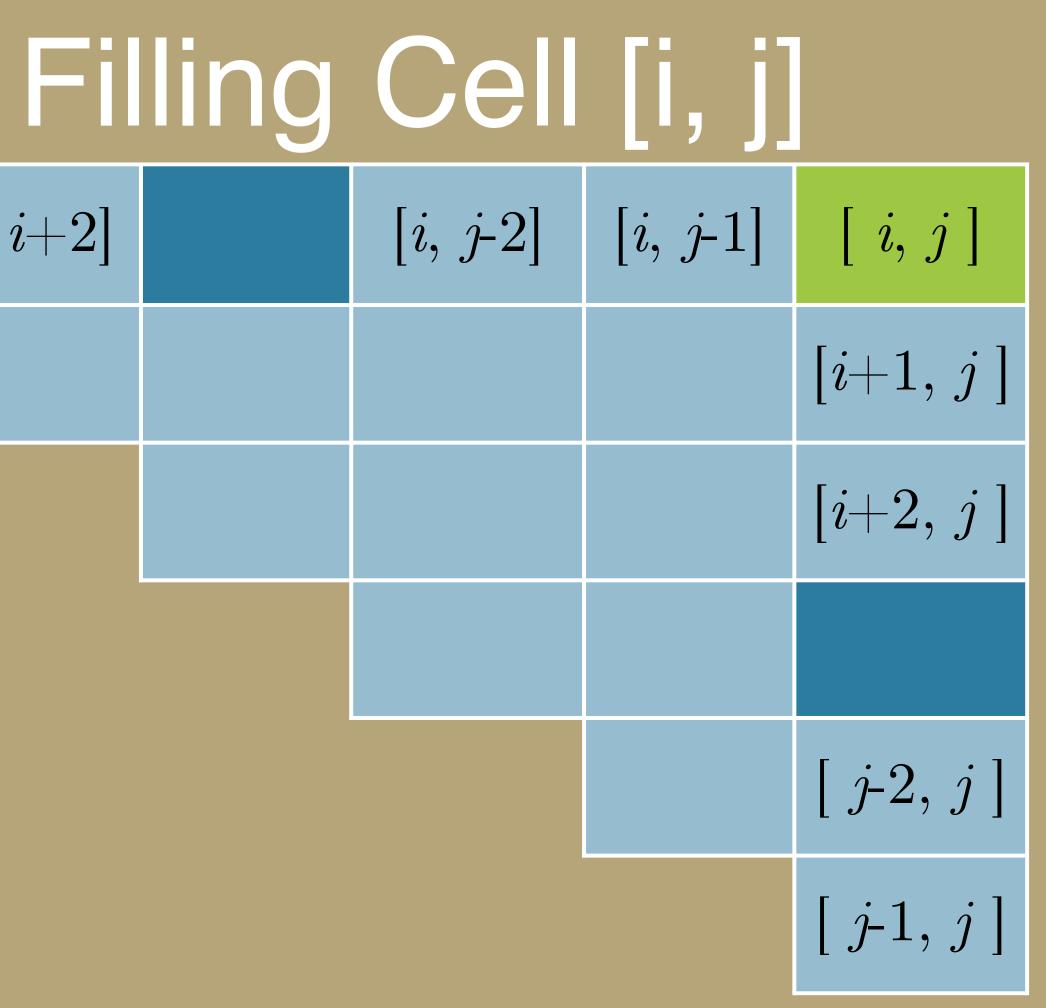






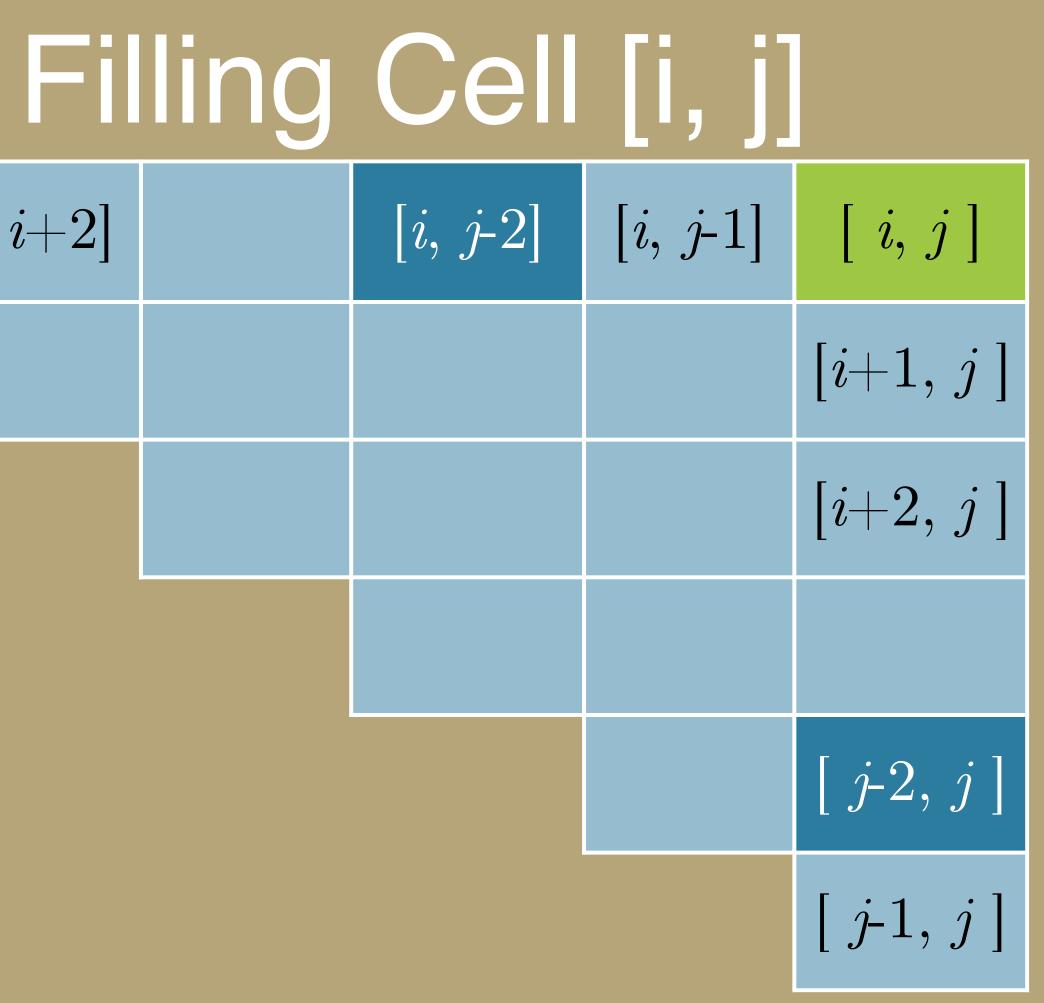


$$[i, i+1]$$
  $[i, i+2]$ 



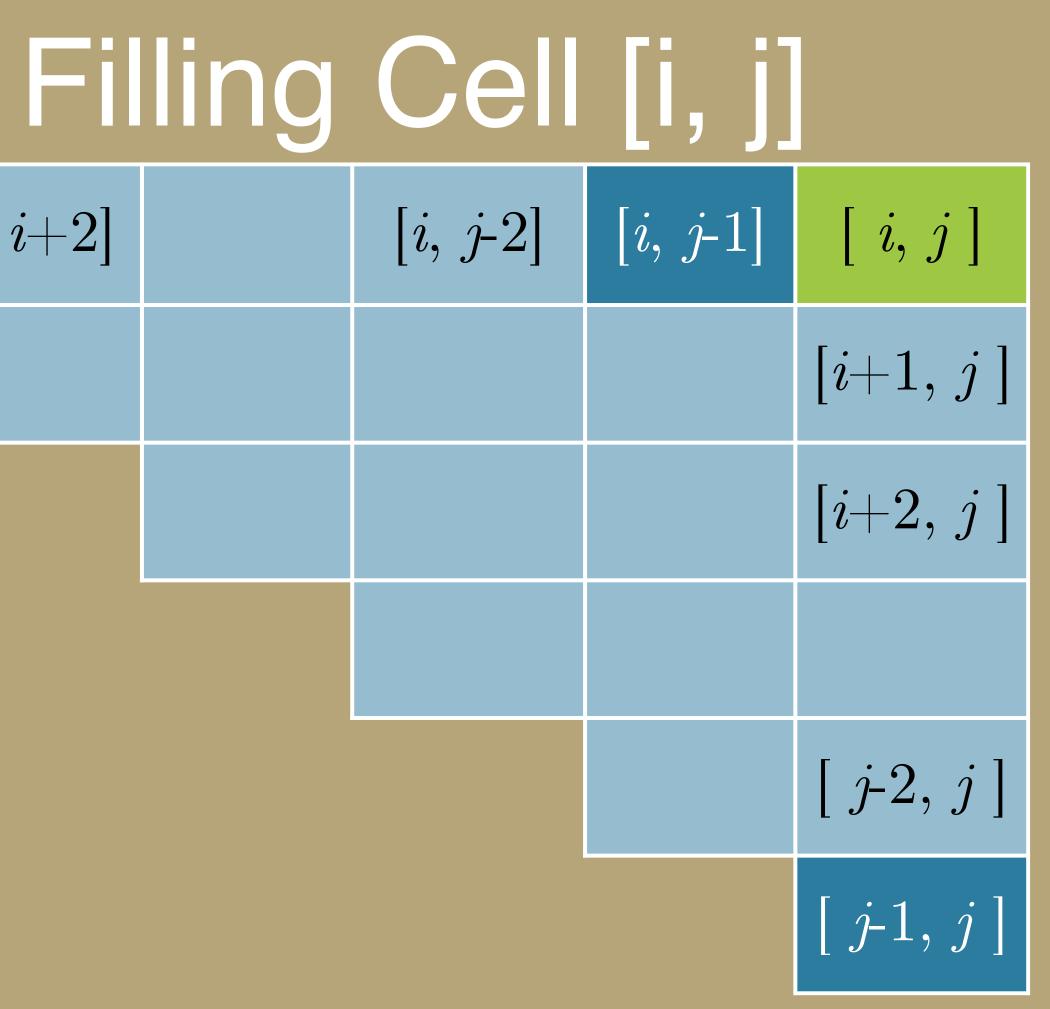


$$[i, i+1]$$
  $[i, i+2]$ 





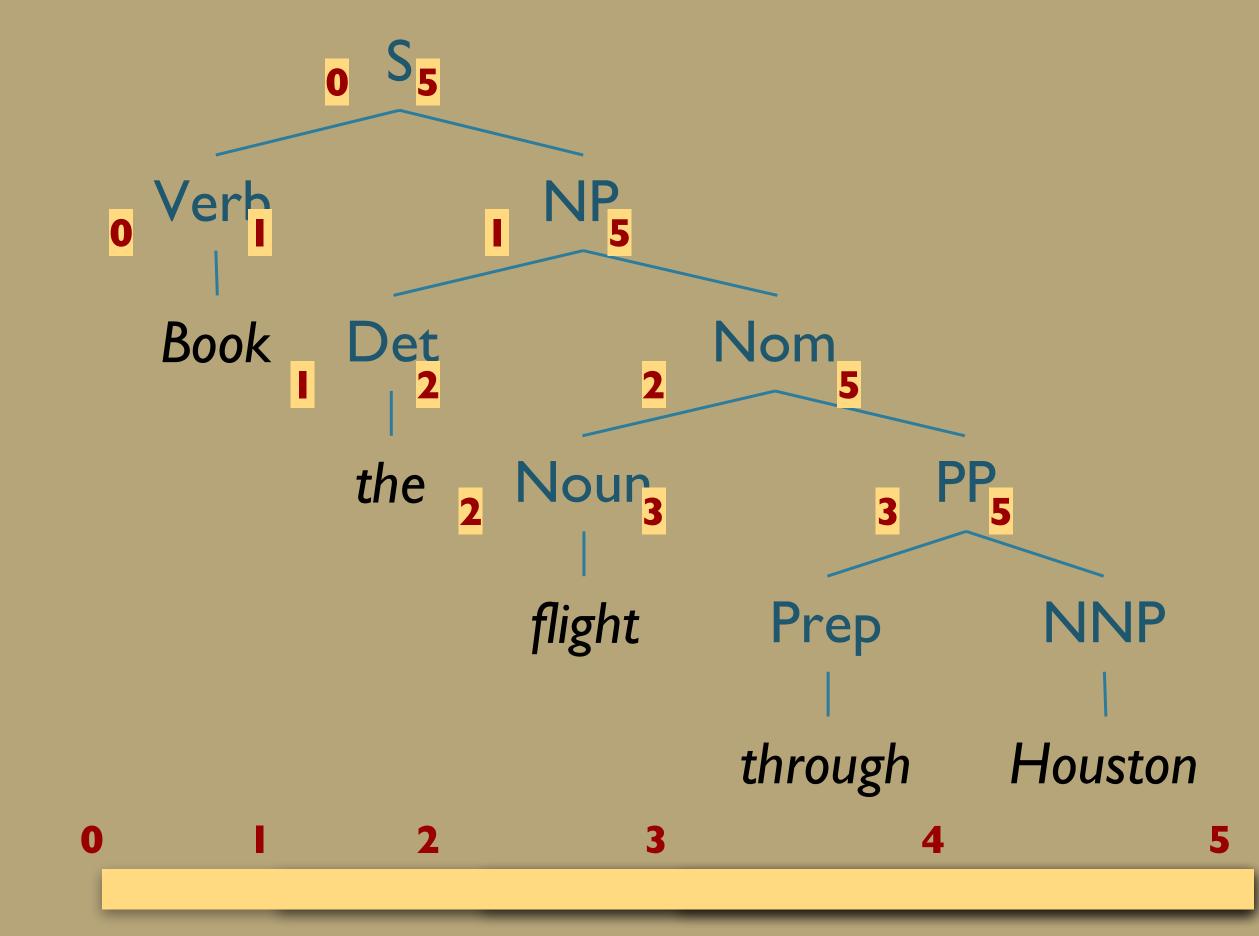
$$[i, i+1]$$
  $[i, i+2]$ 





## Why fill cells this way?

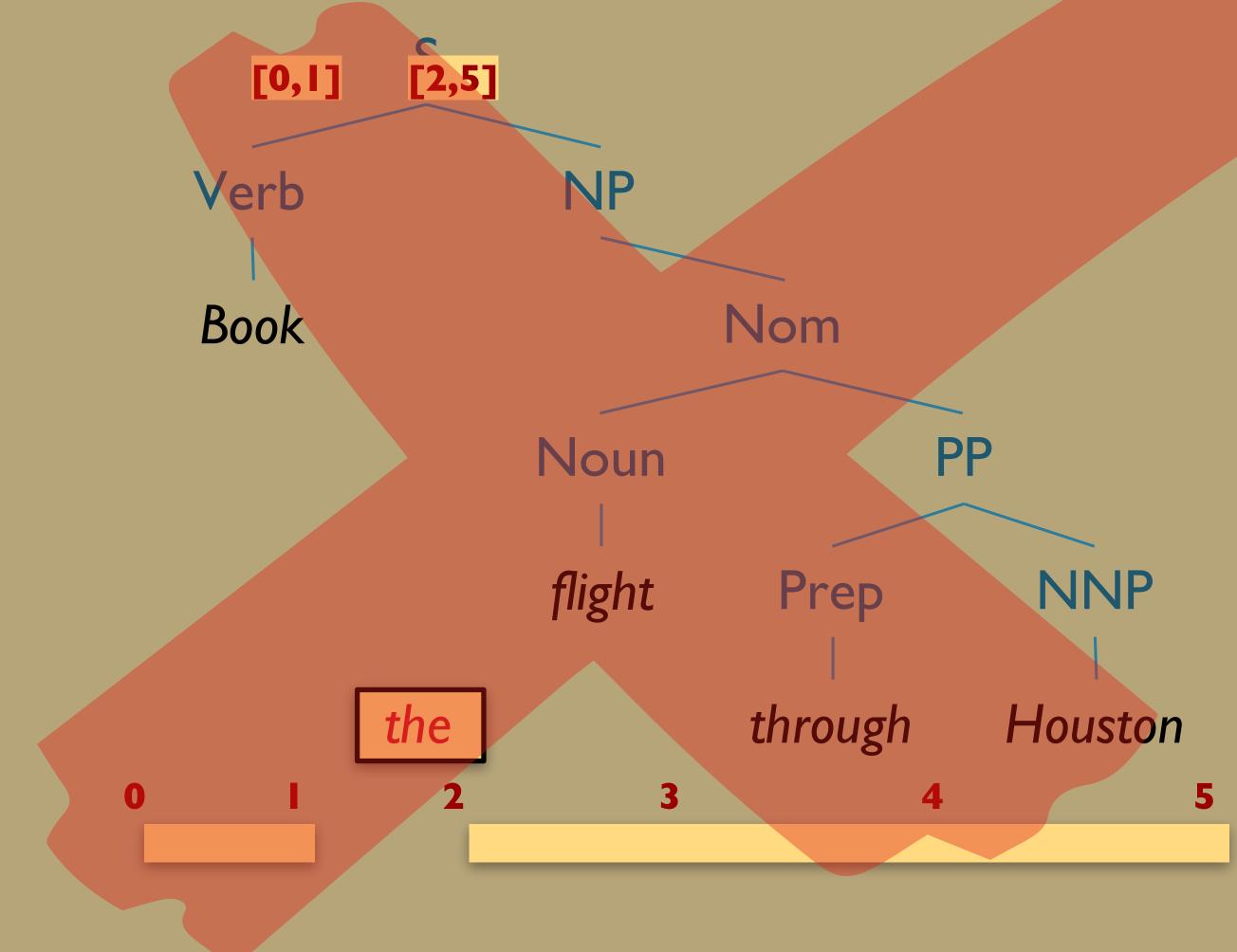
• For cell [ i, j ], must be able to access all cells [i, k ] and [ k, j ] where i < k < j





# Why fill cells this way?

• For cell [ i, j], must be able to access all cells [i, k] and [k, j] where i < k < j





# CKY Parsing Example





### $\mathscr{L}_1$ Grammar $S \rightarrow NP VP$ $S \rightarrow X1 VP$ $X1 \rightarrow Aux NP$ $S \rightarrow book \ | \ include \ | \ prefer$ $S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I / she / me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ Nominal $\rightarrow$ book | flight | meal | money Nominal → Nominal Noun Nominal $\rightarrow$ Nominal PP $VP \rightarrow book \ | \ include \ | \ prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$ -

0

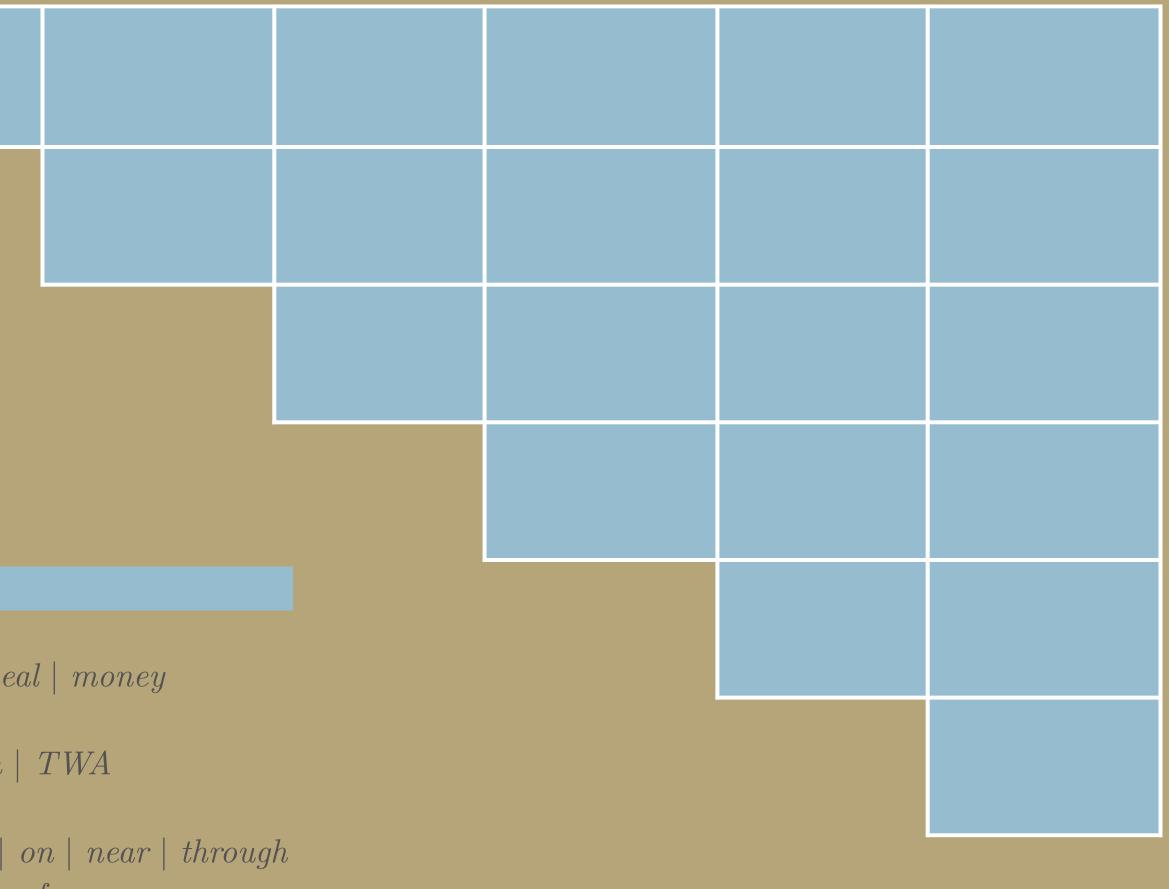
### Lexicon

 $\begin{array}{l} Det \rightarrow that \mid this \mid a \\ Noun \rightarrow book \mid flight \mid meal \mid money \\ Pronoun \rightarrow I \mid she \mid me \\ Proper-Noun \rightarrow Houston \mid TWA \\ Aux \rightarrow does \\ Preposition \rightarrow from \mid to \mid on \mid near \mid through \\ Verb \rightarrow book \mid include \mid prefer \end{array}$ 

þrefer

2

a







$\mathscr{L}_1$ Grammar	
$S \rightarrow NP VP$	
$S \rightarrow X1 \ VP$	
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
$NP \rightarrow TWA \mid Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book / flight / meal / money	т
Nominal → Nominal Noun	Le
$Nominal \rightarrow Nominal PP$	De
$VP \rightarrow book \ / \ include \ / \ prefer$	No
$VP \rightarrow Verb NP$	Pro
$VP \rightarrow X2 PP$	Pro
$X2 \rightarrow Verb NP$	Au Dm
$VP \rightarrow Verb PP$	Pre
$VP \rightarrow VP PP$	Ver
$PP \rightarrow Preposition NP$	
	oref

### NP [0,1]

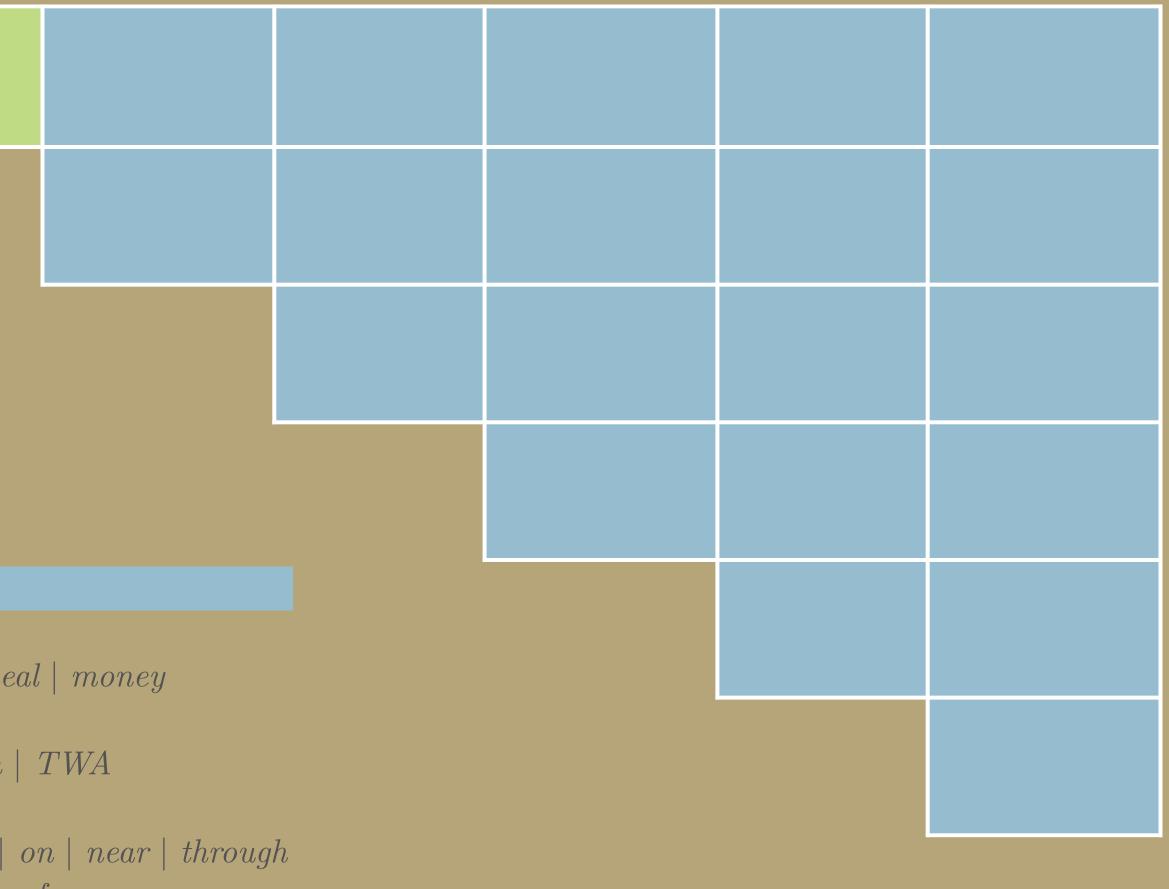
### xicon

 $t \rightarrow that \mid this \mid a$  $un \rightarrow book \mid flight \mid meal \mid money$  $ronoun \rightarrow I \mid she \mid me$  $oper-Noun \rightarrow Houston \mid TWA$  $x \rightarrow does$  $eposition \rightarrow from \mid to \mid on \mid near \mid through$  $rb \rightarrow book \mid include \mid prefer$ 

fer

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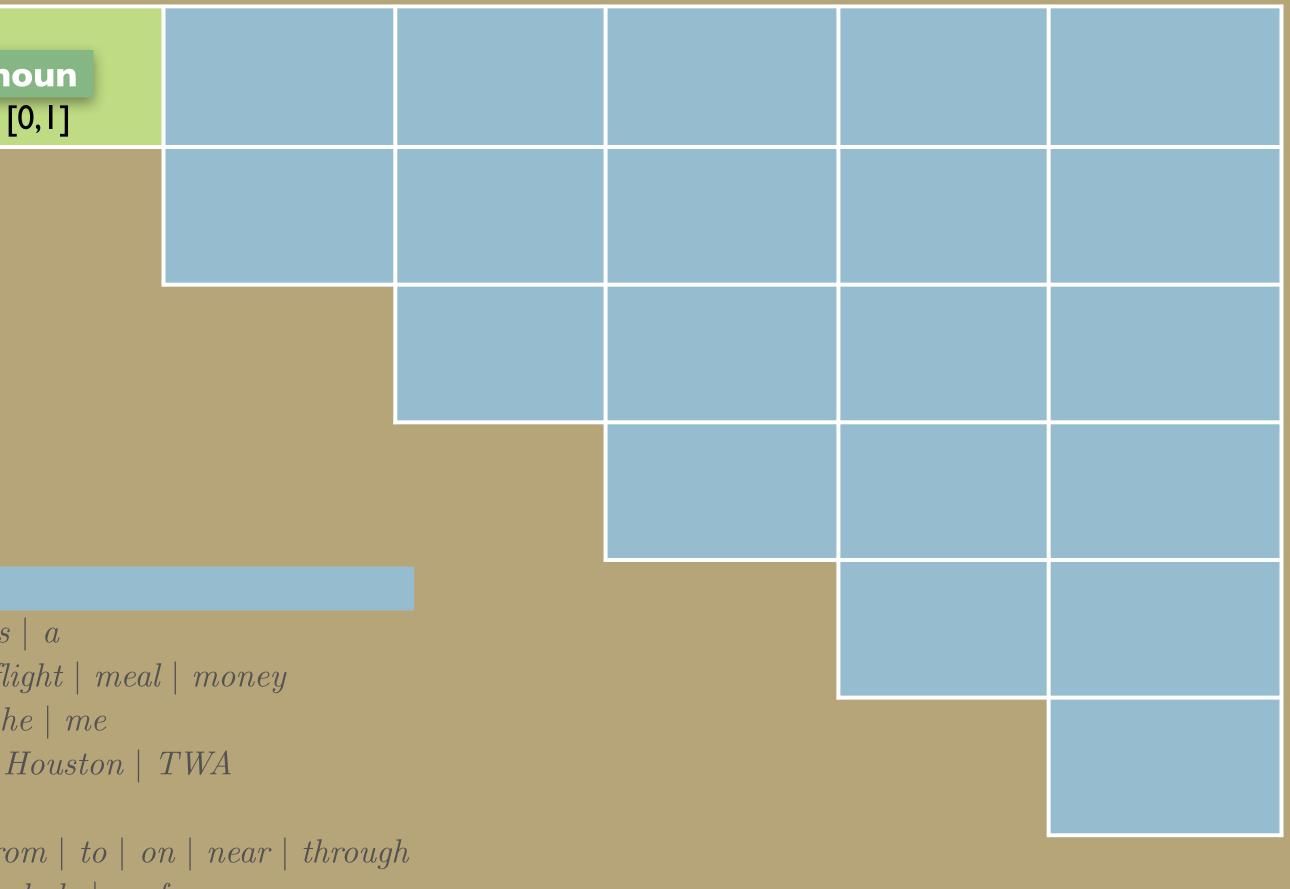
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$\mathscr{L}_1$ Grammar	NP,
$S \rightarrow NP VP$	Pronoun
$S \rightarrow X1 \ VP$	[0,1]
$X1 \rightarrow Aux NP$	
$S \rightarrow book \ / \ include \ / \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
$NP \rightarrow TWA \mid Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book   flight   meal   money	Lexicon
Nominal → Nominal Noun	$Det \rightarrow that \mid this \mid a$
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid me$
$VP \rightarrow book \ / \ include \ / \ prefer$	$\frac{Pronoun}{Pronoun} \rightarrow \frac{I}{I}   she   me$
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid$
$VP \rightarrow X2 PP$	$Aux \rightarrow does$
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid$
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pr$
$VP \rightarrow VP PP$	
$PP \rightarrow Preposition \Lambda$	
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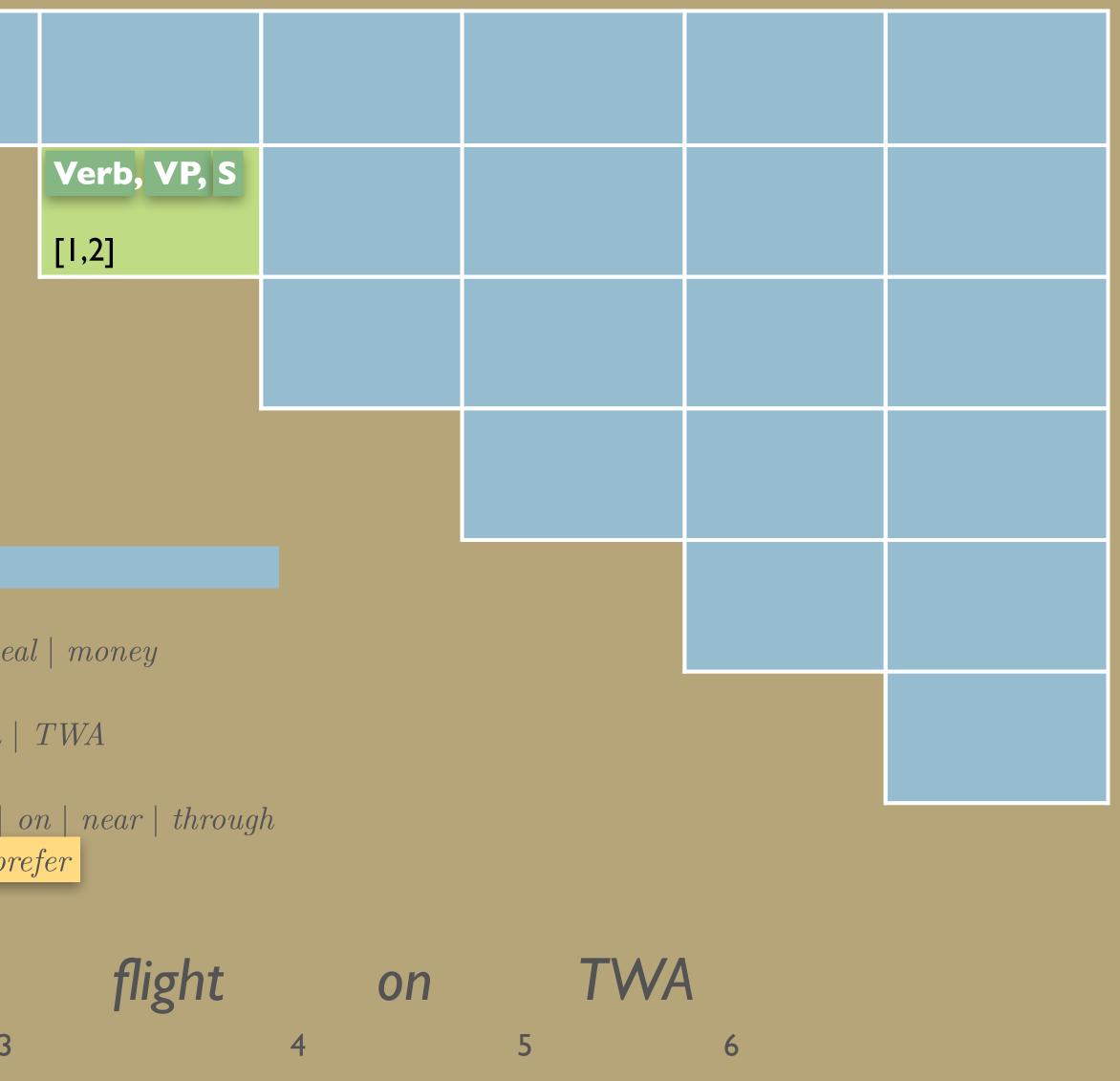


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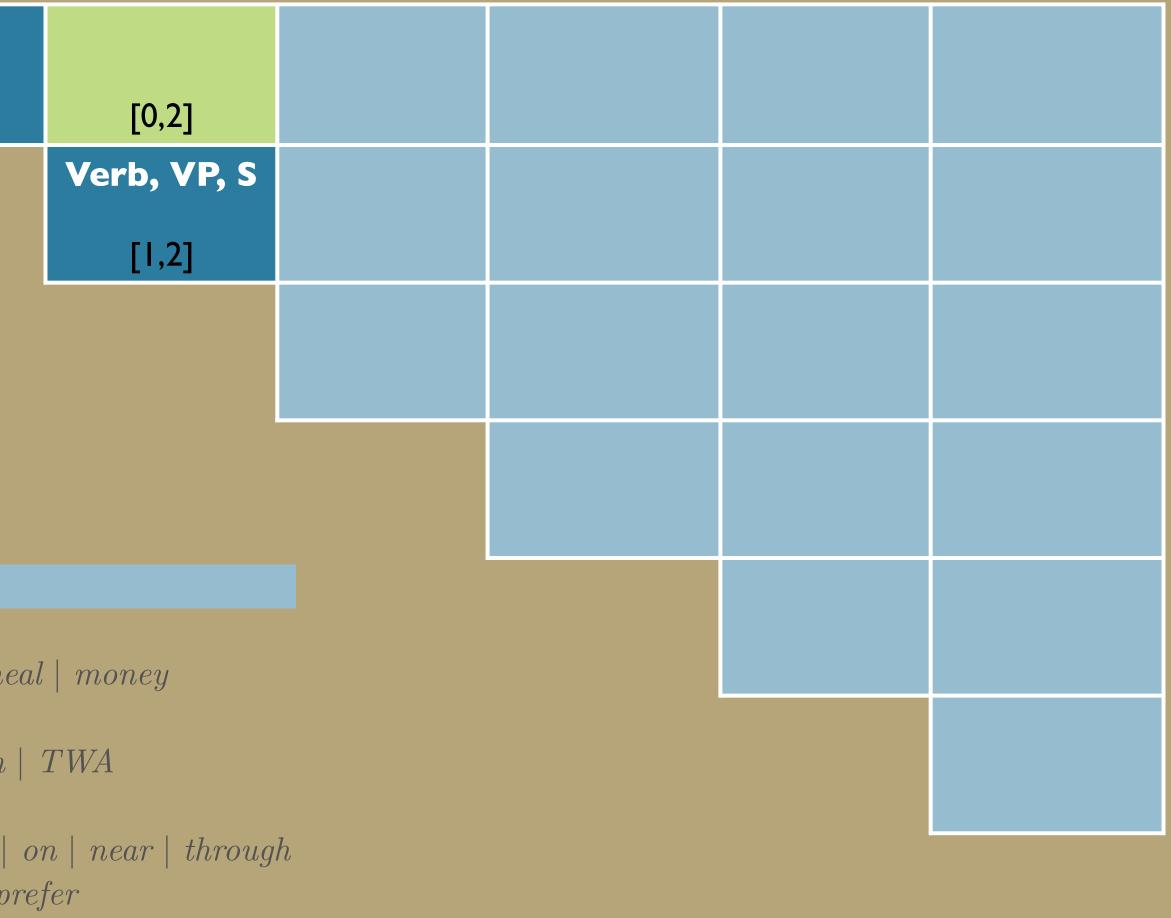


$\mathscr{L}_1$ Grammar	NP,
$S \rightarrow NP VP$	Pronoun
$S \rightarrow X1 VP$	[0,1]
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
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$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
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$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book   flight   meal   money	Louison
Nominal → Nominal Noun	Lexicon
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid mod$
$VP \rightarrow book \   \ include \   \ prefer$	$Noun \rightarrow book \mid flight \mid mee$
$VP \rightarrow Verb NP$	$Pronoun \rightarrow I \mid she \mid me$
$VP \rightarrow X2 PP$	$Proper-Noun \rightarrow Houston \mid \\ Aux \rightarrow does$
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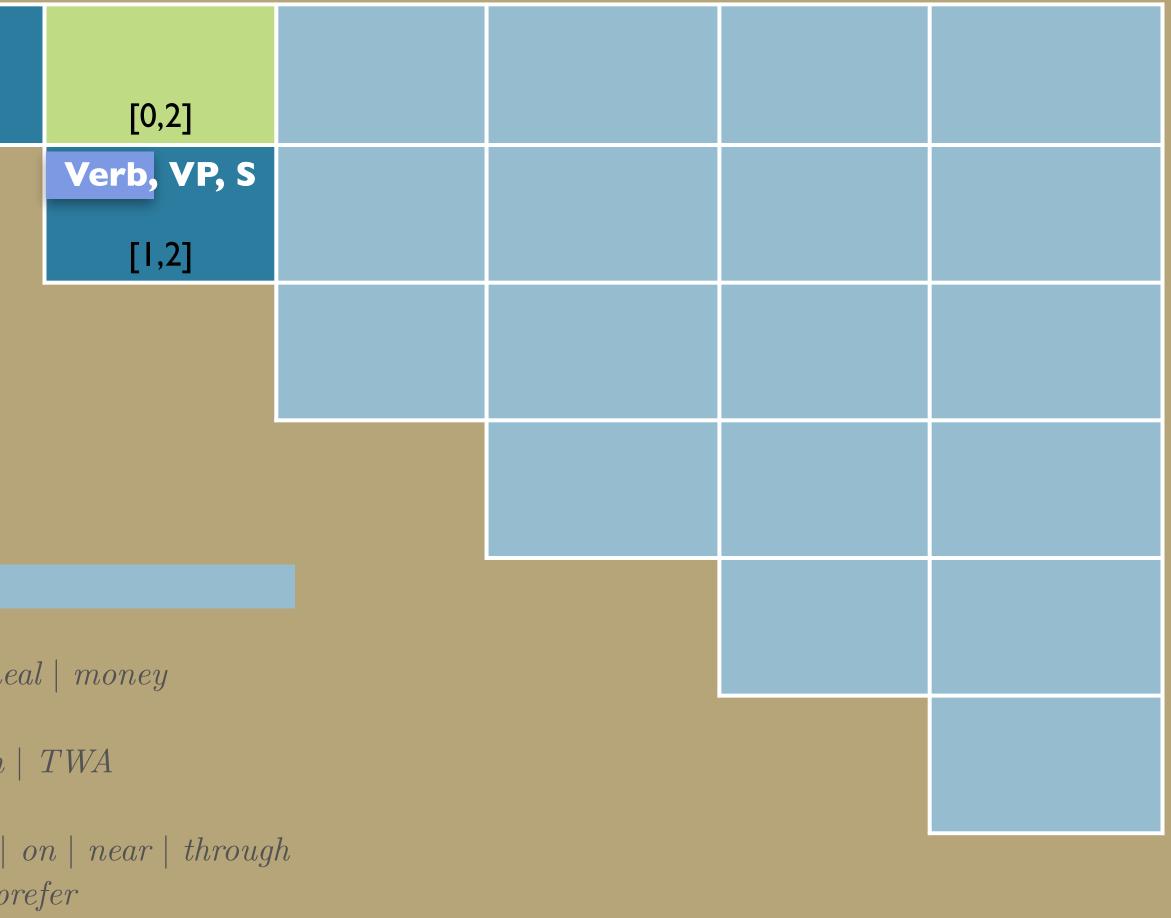
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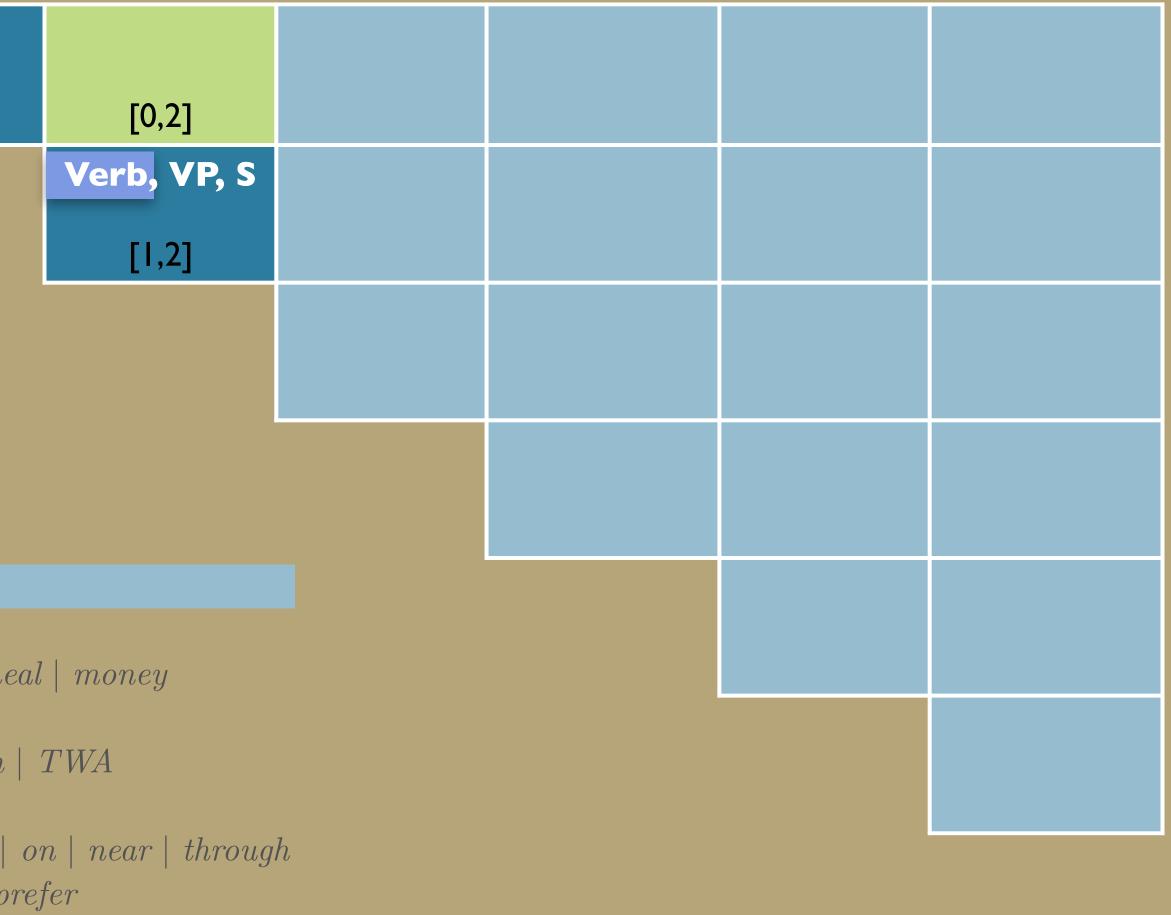
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$VP \rightarrow Verb PP$ $Verb \rightarrow book \mid include \mid$	
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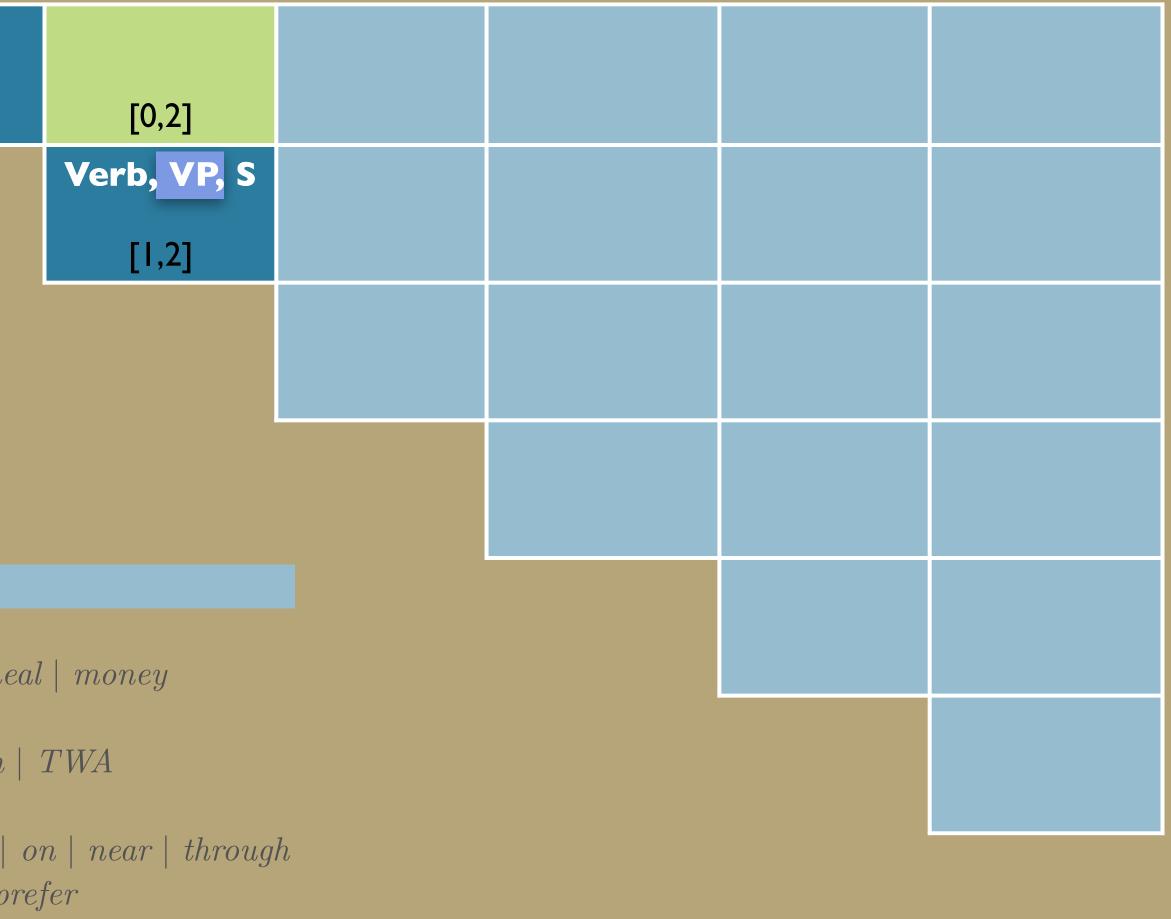
$\mathscr{L}_1$ Grammar	NP
$S \rightarrow NP VP$	Pronoun
$S \rightarrow X1 \ VP$	[0,1]
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
$NP \rightarrow TWA \ / Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book / flight / meal / money	т •
Nominal   Nominal Noun	Lexicon
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that \mid this \mid a$
$VP \rightarrow book \   \ include \   \ prefer$	$Noun \rightarrow book \mid flight \mid mee$
$VP \rightarrow Verb NP$	$Pronoun \rightarrow I \mid she \mid me$
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$X2 \rightarrow Verb NP$	$Aux \rightarrow does$
$VP \rightarrow Verb PP$	$Preposition \rightarrow from \mid to \mid$ $Vorh \rightarrow book \mid include \mid nn$
$VP \rightarrow VP PP$	$Verb \rightarrow book \mid include \mid pr$
$PP \rightarrow Preposition$	
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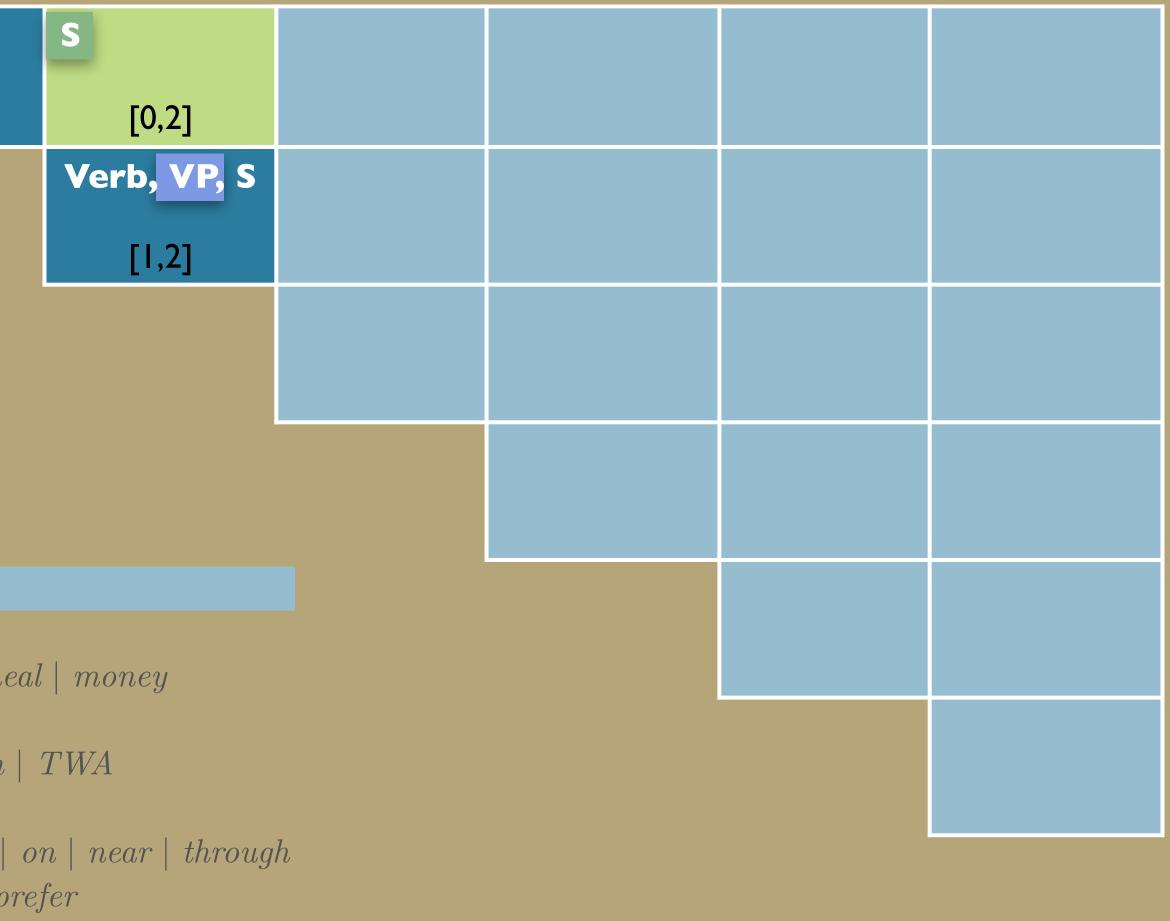
$\mathcal{Y}_{1}$ GrammarNP $S \rightarrow NP VP$ Pronoun $S \rightarrow X1 VP$ [0,1] $X1 \rightarrow Aux NP$ $[0,1]$ $S \rightarrow book   include   prefer$ $S \rightarrow Verb NP$ $S \rightarrow Verb NP$ $S \rightarrow Verb PP$ $S \rightarrow Verb PP$ $S \rightarrow Verb PP$ $S \rightarrow Verb PP$ $NP \rightarrow TWA   Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book   flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Det \rightarrow that   this   a$ $Nominal \rightarrow Nominal Noun$ $Noun \rightarrow book   flight   meal PP$ $VP \rightarrow book   include   prefer$ $Pronoun \rightarrow I   she   me$	
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$NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det \ Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verh \ NP$ $Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid she$ $Pronoun \rightarrow I \mid she \mid me$	
$NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verh NP$ $Iushe \mid money$ $Pronoun \rightarrow I \mid she \mid money$	
$NP \rightarrow Det Nominal$ $Nominal \rightarrow book   flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book   include   prefer$ $VP \rightarrow Verb NP$ $I = Verb NP$	
$NP \rightarrow Det Nominal$ $Nominal \rightarrow book   flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book   include   prefer$ $VP \rightarrow Verb NP$ $I = Verb NP$	
$\begin{array}{l} Nominal \rightarrow Nominal Noun \\ Nominal \rightarrow Nominal PP \\ \hline VP \rightarrow book \   \ include \   \ prefer \\ VP \rightarrow Verh \ NP \end{array}$	
$VP \rightarrow X2 PP$ $VP \rightarrow X2 PP$ $Aux \rightarrow does$ $Proper-Noun \rightarrow Houston$	2
$X2 \rightarrow Verb \ NP$ $Preposition \rightarrow from \mid to$	
$VP \rightarrow Verb PP$ $Verb \rightarrow book \mid include \mid$	
$VP \rightarrow VP PP$	
$PP \rightarrow Preposition$	
l prefer a	
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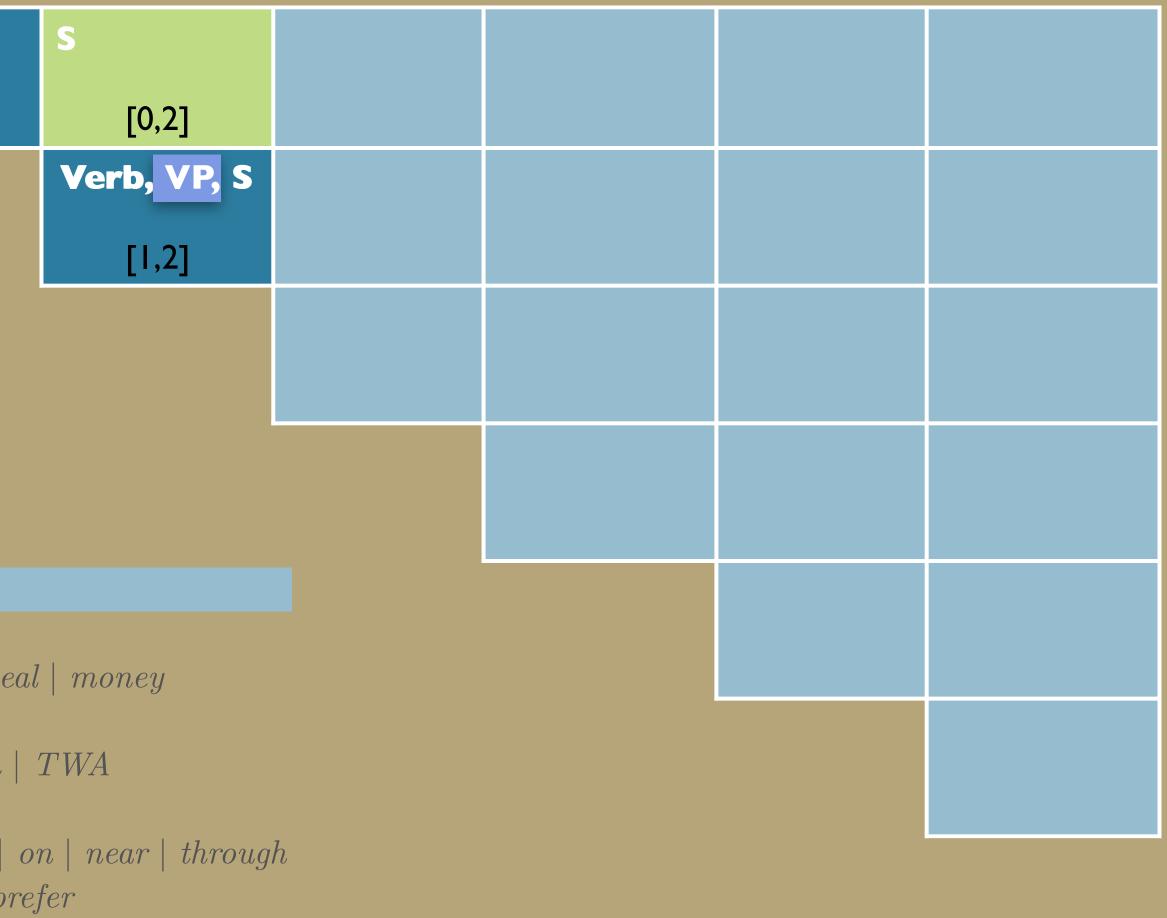
$\begin{array}{c} \mathscr{L}_{1} \text{ Grammar} \\ S \rightarrow NP \ VP \\ S \rightarrow X1 \ VP \\ X1 \rightarrow Aux \ NP \\ S \rightarrow back \ in cloude \ l \ amefore \end{array}$	NP, Pronoun [0,1]
$S \rightarrow book \   \ include \   \ prefer$ $S \rightarrow Verb \ NP$ $S \rightarrow X2 \ PP$ $S \rightarrow Verb \ PP$ $S \rightarrow VP \ PP$ $NP \rightarrow I \   \ she \   \ me$ $NP \rightarrow TWA \   \ Houston$ $NP \rightarrow Det \ Nominal$	
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \ / \ include \ / \ prefer$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$ $VP \rightarrow Verb \ PP$ $PP \rightarrow Preposition$	Lexicon $Det \rightarrow that   this   a$ $Noun \rightarrow book   flight   meanPronoun \rightarrow I   she   meProper-Noun \rightarrow Houston  Aux \rightarrow doesPreposition \rightarrow from   to   aVerb \rightarrow book   include   properation  $
	prefer a 2 3







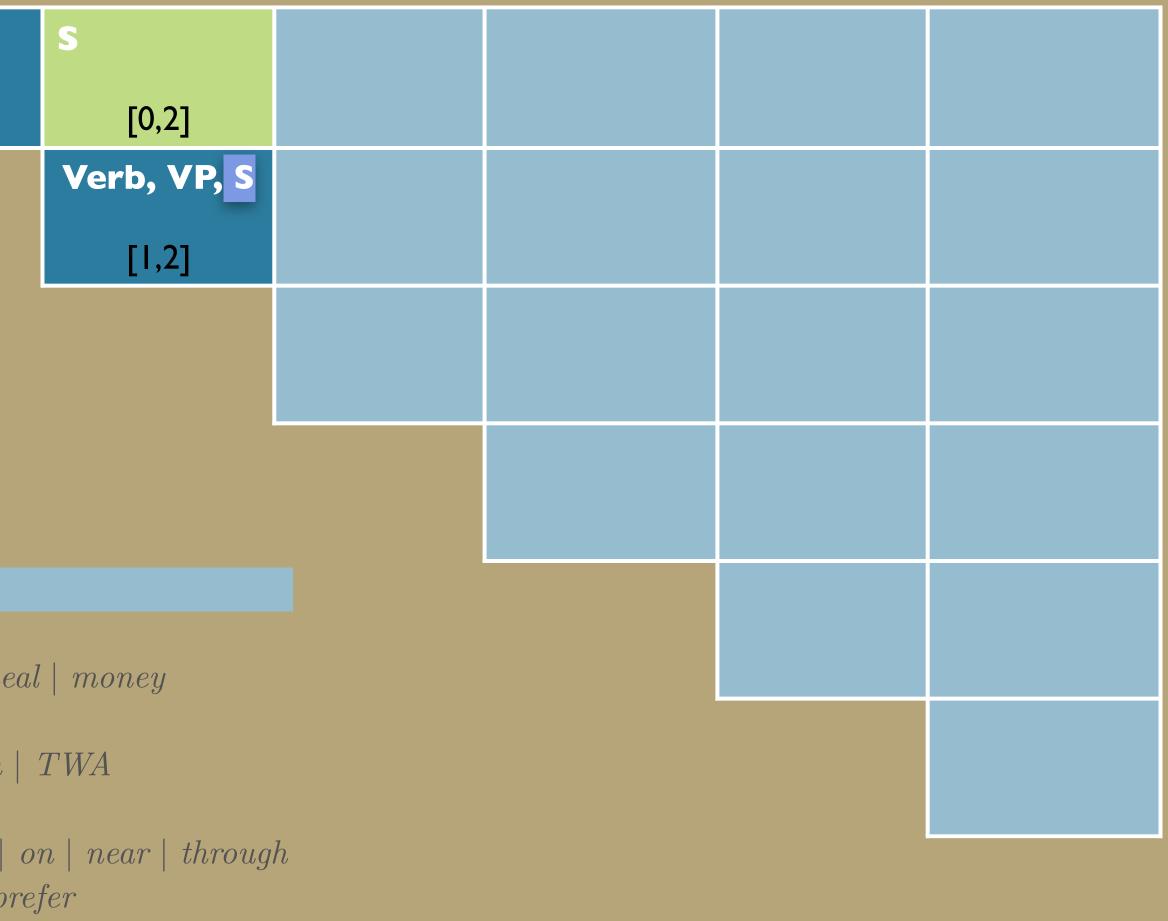
$\mathscr{L}_1$ Grammar	NP
$S \rightarrow NP VP$	Pronoun
$S \rightarrow X1 \ VP$	[0,1]
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	-
$NP \rightarrow TWA / Houston$	
$NP \rightarrow Det Nominal$	
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \ / \ include \ / \ prefer$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$ $VP \rightarrow VP \ PP$	- <b>Lexicon</b> $Det \rightarrow that   this   a$ $Noun \rightarrow book   flight   means Pronoun \rightarrow I   she   meProper-Noun \rightarrow Houston  Aux \rightarrow doesPreposition \rightarrow from   to  Verb \rightarrow book   include   propertion$
$PP \rightarrow Preposition$	
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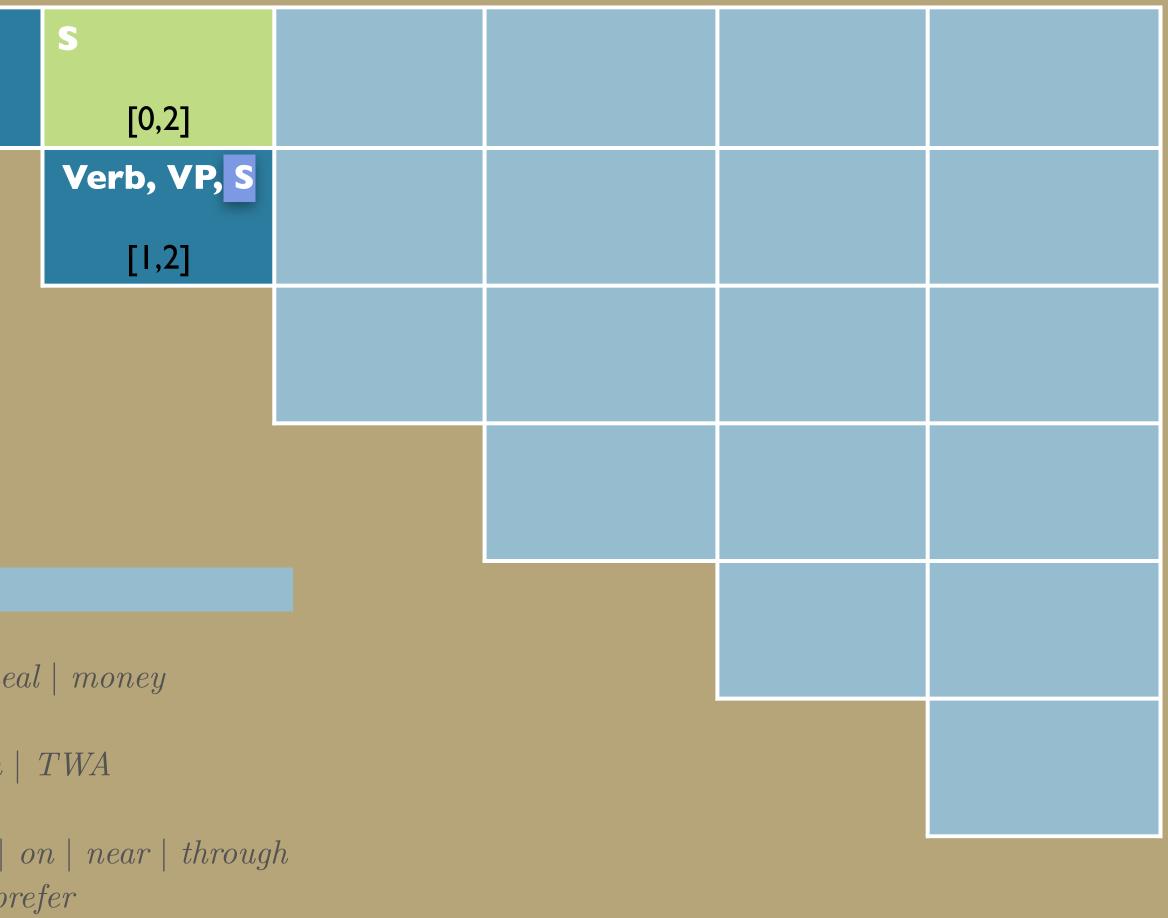
$\mathcal{Y}_{1}$ GrammarNP $S \rightarrow NP VP$ Pronoun $S \rightarrow X1 VP$ [0,1] $X1 \rightarrow Aux NP$ $[0,1]$ $S \rightarrow book   include   prefer$ $S \rightarrow Verb NP$ $S \rightarrow Verb NP$ $S \rightarrow Verb PP$ $S \rightarrow Verb PP$ $S \rightarrow Verb PP$ $S \rightarrow Verb PP$ $NP \rightarrow TWA   Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book   flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Det \rightarrow that   this   a$ $Nominal \rightarrow Nominal Noun$ $Noun \rightarrow book   flight   meal PP$ $VP \rightarrow book   include   prefer$ $Pronoun \rightarrow I   she   me$	
$X1 \rightarrow Aux NP$ $S \rightarrow book   include   prefer$ $S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I   she   me$ $NP \rightarrow TWA   Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book   flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book   include   prefer$ $VP \rightarrow Verh NP$ $Det \rightarrow that   this   a$ $Noun \rightarrow book   flight   meal   money$ $Pronoun \rightarrow I   she   meal   money$	
$S \rightarrow book \mid include \mid prefer$ $S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb NP$ $Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid meal \mid money$ $Pronoun \rightarrow I \mid she \mid meal \mid money$ $Pronoun \rightarrow I \mid she \mid meal \mid money$	
$S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal Noun$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb NP$ $Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid meal \mid money$ $VP \rightarrow Verb NP$	
$S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal Noun$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verh NP$ $Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid she$ $Pronoun \rightarrow I \mid she \mid mo$	
$S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal Noun$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb NP$ $Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid she$ $Pronoun \rightarrow I \mid she \mid mo$	
$S \rightarrow VP PP$ $NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det \ Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb \ NP$ $Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid e$ $Pronoun \rightarrow I \mid she \mid me$	
$NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det \ Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verh \ NP$ $Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid she$ $Pronoun \rightarrow I \mid she \mid me$	
$NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verh NP$ $Iushe \mid money$ $Pronoun \rightarrow I \mid she \mid money$	
$NP \rightarrow Det Nominal$ $Nominal \rightarrow book   flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book   include   prefer$ $VP \rightarrow Verb NP$ $I = Verb NP$	
$NP \rightarrow Det Nominal$ $Nominal \rightarrow book   flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book   include   prefer$ $VP \rightarrow Verb NP$ $I = Verb NP$	
$\begin{array}{l} Nominal \rightarrow Nominal Noun \\ Nominal \rightarrow Nominal PP \\ \hline VP \rightarrow book \   \ include \   \ prefer \\ VP \rightarrow Verh \ NP \end{array}$	
$VP \rightarrow X2 PP$ $VP \rightarrow X2 PP$ $Aux \rightarrow does$ $Proper-Noun \rightarrow Houston$	2
$X2 \rightarrow Verb \ NP$ $Preposition \rightarrow from \mid to$	
$VP \rightarrow Verb PP$ $Verb \rightarrow book \mid include \mid$	
$VP \rightarrow VP PP$	
$PP \rightarrow Preposition$	
l prefer a	
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$\mathscr{L}_1$ Grammar	NP
$S \rightarrow NP VP$	Pronoun
$S \rightarrow X1 \ VP$	[0,1]
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	-
$NP \rightarrow TWA / Houston$	
$NP \rightarrow Det Nominal$	
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \ / \ include \ / \ prefer$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$ $VP \rightarrow VP \ PP$	- <b>Lexicon</b> $Det \rightarrow that   this   a$ $Noun \rightarrow book   flight   means Pronoun \rightarrow I   she   meProper-Noun \rightarrow Houston  Aux \rightarrow doesPreposition \rightarrow from   to  Verb \rightarrow book   include   propertion$
$PP \rightarrow Preposition$	
	prefer a
0	2 3







$\mathscr{L}_1$ Grammar	
$S \rightarrow NP VP$	
$S \rightarrow X1 VP$	
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
$NP \rightarrow TWA \mid Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book   flight   meal   money	Lexicon
Nominal → Nominal Noun	$Det \rightarrow that$
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow bc$
$VP \rightarrow book \ / \ include \ / \ prefer$	Pronoun
$VP \rightarrow Verb NP$	Proper-Nov
$VP \rightarrow X2 PP$	$Aux \rightarrow doe$
$X2 \rightarrow Verb NP$	Preposition
$VP \rightarrow Verb PP$	$Verb \rightarrow boo$
$VP \rightarrow VP PP$	
$PP \rightarrow Preposition NP$	
	prefer
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NP, Pronoun [0,1]

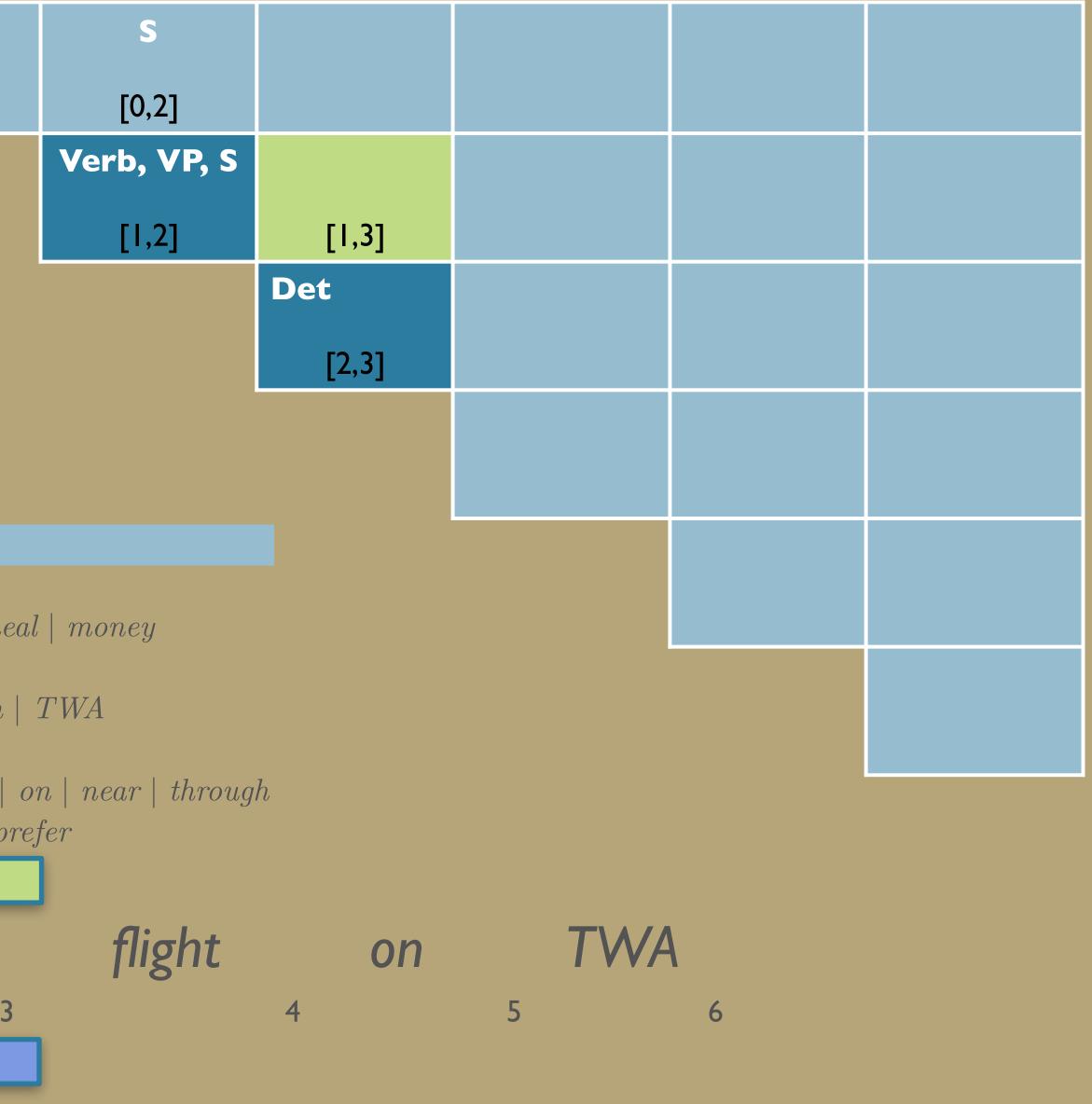
 $\begin{array}{l} Det \rightarrow that \mid this \mid a \\ Noun \rightarrow book \mid flight \mid me \\ Pronoun \rightarrow I \mid she \mid me \\ Proper-Noun \rightarrow Houston \\ Aux \rightarrow does \\ Preposition \rightarrow from \mid to \mid \\ Verb \rightarrow book \mid include \mid pe \end{array}$ 

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	S				
	[0,2]				
	Verb, VP, S				
	[1,2]				
		Det			
		[2,3]			
real	money				
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or pref	n   near   throug <sup>c</sup> er	h			
	flight	on	TWA	1	
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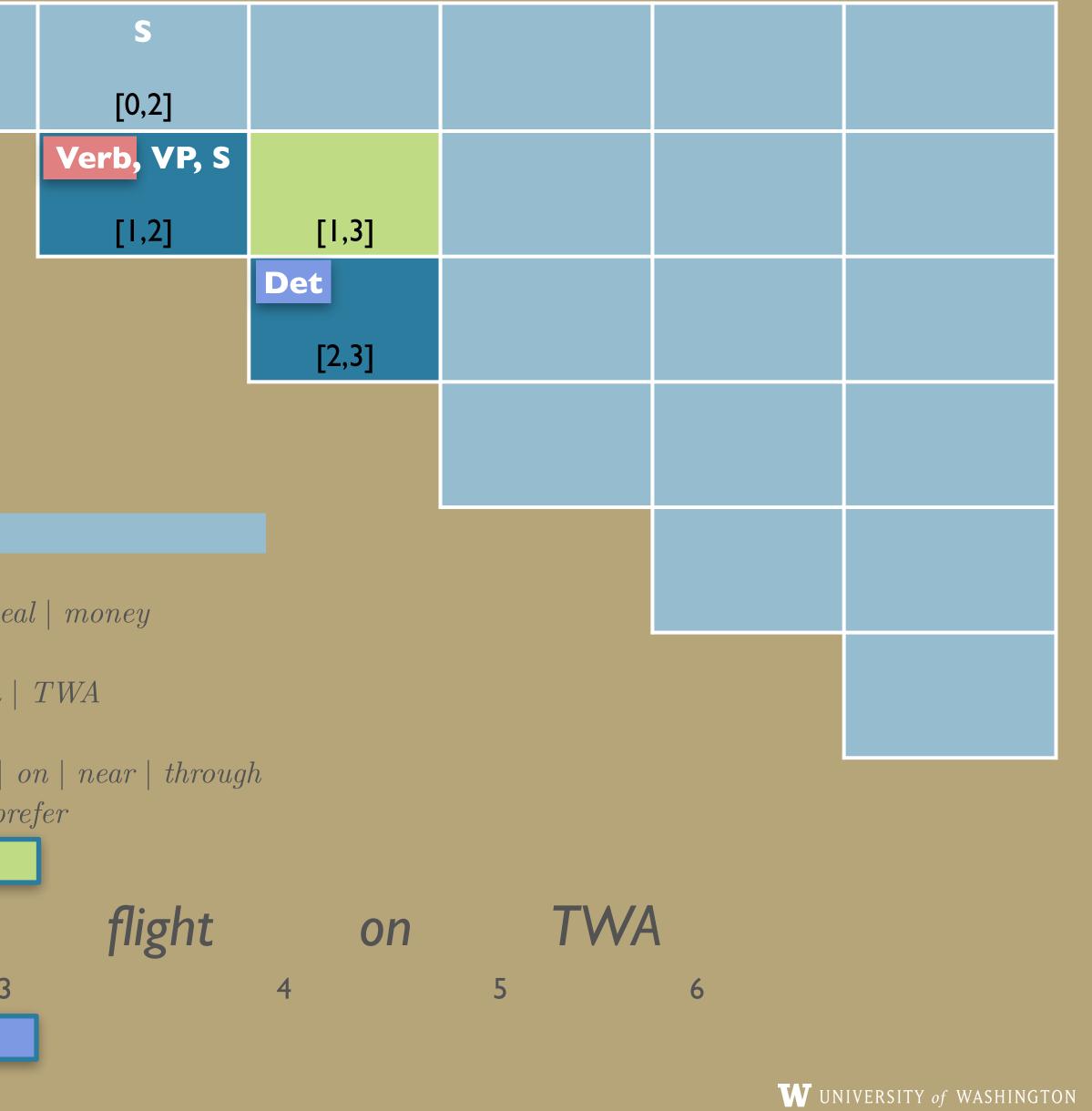


$\mathscr{L}_1$ Grammar	NP,	
$S \rightarrow NP VP$	Pronoun	
$S \rightarrow X1 \ VP$	[0,1]	
$X1 \rightarrow Aux NP$		
$S \rightarrow book \   \ include \   \ prefer$		
$S \rightarrow Verb NP$		
$S \rightarrow X2 PP$		
$S \rightarrow Verb PP$		
$S \rightarrow VP PP$		
$NP \rightarrow I / she / me$		
$NP \rightarrow TWA / Houston$		
$NP \rightarrow Det Nominal$		
$\begin{array}{l} Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money \\ Nominal \rightarrow Nominal \ Noun \\ Nominal \rightarrow Nominal \ PP \\ VP \rightarrow book \ / \ include \ / \ prefer \\ VP \rightarrow Verb \ NP \\ VP \rightarrow Verb \ NP \\ VP \rightarrow X2 \ PP \\ X2 \rightarrow Verb \ NP \\ VP \rightarrow Verb \ PP \\ VP \rightarrow Verb \ PP \\ PP \rightarrow Preposition \ NP \end{array}$	Lexicon $Det \rightarrow that   this   a$ $Noun \rightarrow book   flight   meanPronoun \rightarrow I   she   meProper-Noun \rightarrow Houston  Aux \rightarrow doesPreposition \rightarrow from   to  Verb \rightarrow book   include   pr$	0
$PP \rightarrow Preposition NP$		
	prefer a	
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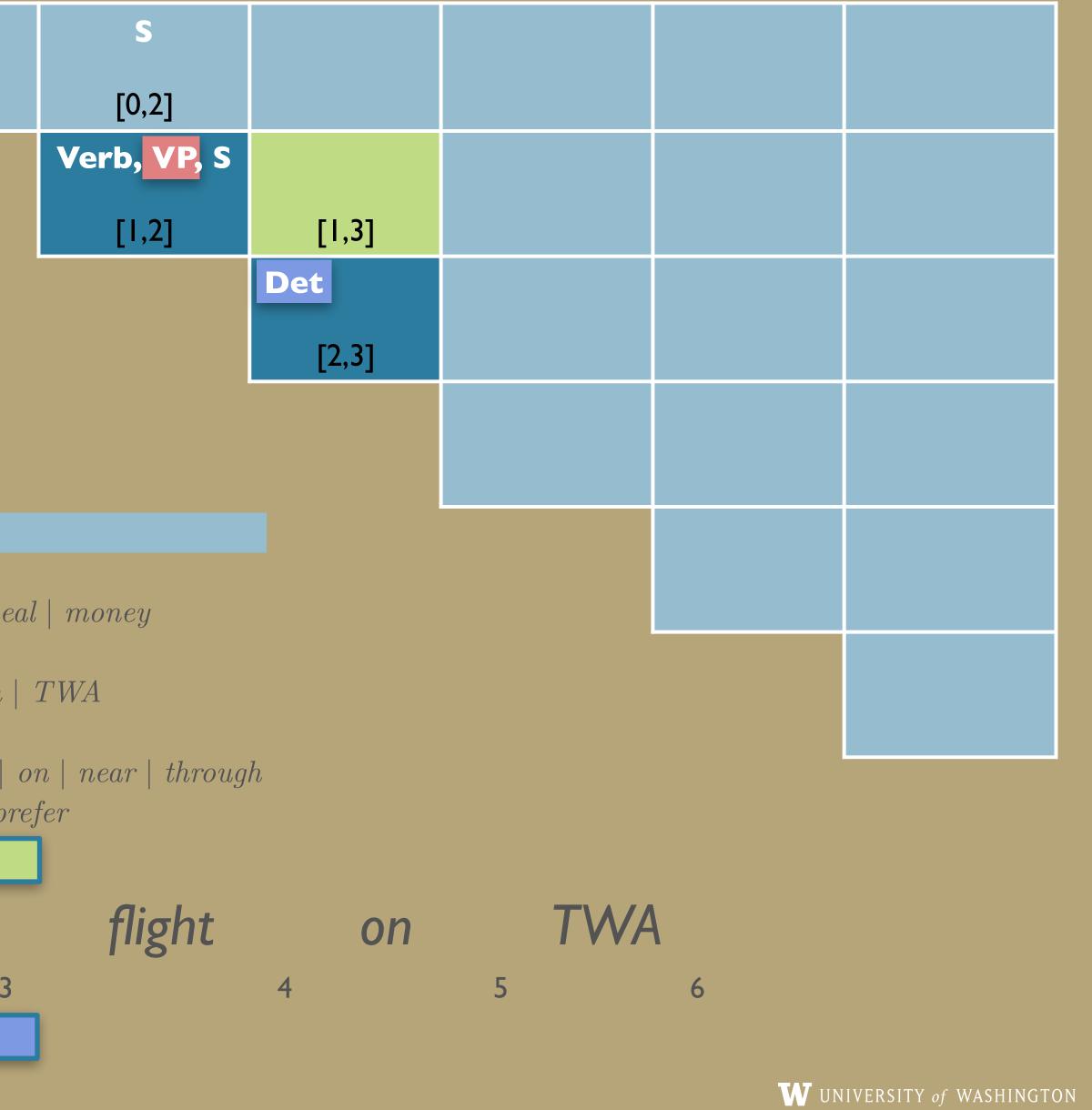


$\mathscr{L}_1$ Grammar		NP,
$S \rightarrow NP VP$		Pronoun
$S \rightarrow X1 VP$		[0,1]
$X1 \rightarrow Aux NP$		
$S \rightarrow book \ / \ include \ / \ prefer$		
$S \rightarrow Verb NP$		
$S \rightarrow X2 PP$		
$S \rightarrow Verb PP$		
$S \rightarrow VP PP$		
$NP \rightarrow I / she / me$		
$NP \rightarrow TWA / Houston$		
$NP \rightarrow Det Nominal$		
$Nominal \rightarrow book \   \ flight \   \ meal \   \ moneg$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \   \ include \   \ prefer$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$ $VP \rightarrow VP \ PP$	$Det \rightarrow that$ $Noun \rightarrow bo$ $Pronoun \rightarrow$ $Proper-Nou$ $Aux \rightarrow doe$ $Preposition$	$ok \mid flight \mid mea$ $I \mid she \mid me$ $an \rightarrow Houston \mid n$
$PP \rightarrow Preposition NP$		
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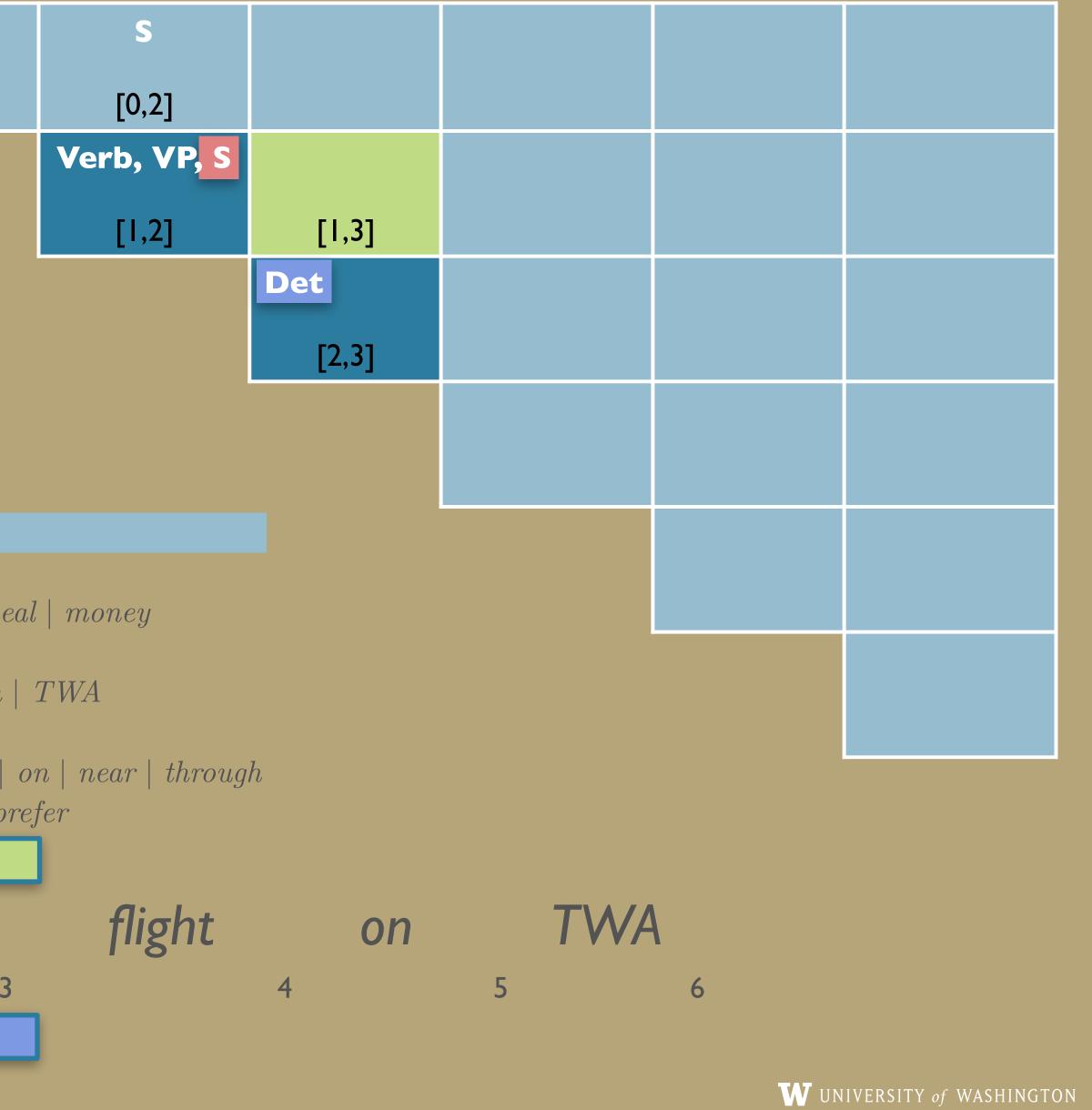


$\mathscr{L}_1$ Grammar	NP,	
$S \rightarrow NP VP$	Pronoun	
$S \rightarrow X1 VP$	[0,1]	
$X1 \rightarrow Aux NP$		
$S \rightarrow book \   \ include \   \ prefer$		
$S \rightarrow Verb NP$		
$S \rightarrow X2 PP$		
$S \rightarrow Verb PP$		
$S \rightarrow VP PP$		
$NP \rightarrow I / she / me$		
$NP \rightarrow TWA / Houston$		
$NP \rightarrow Det Nominal$		
$\begin{array}{l} Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money \\ Nominal \rightarrow Nominal \ Noun \\ Nominal \rightarrow Nominal \ PP \\ VP \rightarrow book \ / \ include \ / \ prefer \\ VP \rightarrow Verb \ NP \\ VP \rightarrow Verb \ NP \\ VP \rightarrow X2 \ PP \\ X2 \rightarrow Verb \ NP \\ VP \rightarrow Verb \ PP \\ VP \rightarrow Verb \ PP \\ PP \rightarrow Preposition \ NP \end{array}$	Lexicon $Det \rightarrow that   this   a$ $Noun \rightarrow book   flight   meanPronoun \rightarrow I   she   meProper-Noun \rightarrow Houston  Aux \rightarrow doesPreposition \rightarrow from   to  Verb \rightarrow book   include   pr$	0
$PP \rightarrow Preposition NP$		
	prefer a	
0 I	2 3	





$\mathscr{L}_1$ Grammar	NP,	
$S \rightarrow NP VP$	Pronoun	
$S \rightarrow X1 VP$	[0,1]	
$X1 \rightarrow Aux NP$		
$S \rightarrow book \   \ include \   \ prefer$		
$S \rightarrow Verb NP$		
$S \rightarrow X2 PP$		
$S \rightarrow Verb PP$		
$S \rightarrow VP PP$		
$NP \rightarrow I / she / me$		
$NP \rightarrow TWA / Houston$		
$NP \rightarrow Det Nominal$		
$\begin{array}{l} Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money \\ Nominal \rightarrow Nominal \ Noun \\ Nominal \rightarrow Nominal \ PP \\ VP \rightarrow book \ / \ include \ / \ prefer \\ VP \rightarrow Verb \ NP \\ VP \rightarrow Verb \ NP \\ VP \rightarrow X2 \ PP \\ X2 \rightarrow Verb \ NP \\ VP \rightarrow Verb \ PP \\ VP \rightarrow Verb \ PP \\ PP \rightarrow Preposition \ NP \end{array}$	Lexicon $Det \rightarrow that   this   a$ $Noun \rightarrow book   flight   meanPronoun \rightarrow I   she   meProper-Noun \rightarrow Houston  Aux \rightarrow doesPreposition \rightarrow from   to  Verb \rightarrow book   include   pr$	0
$PP \rightarrow Preposition NP$		
	prefer a	
0 I	2 3	





$\mathscr{L}_1$ Grammar	NP,	S				
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]				
$X1 \rightarrow Aux NP$		Verb, VP, S				
$S \rightarrow book \ / \ include \ / \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]			
$S \rightarrow X2 PP$			Det			
$S \rightarrow Verb PP$			Det			
$S \rightarrow VP PP$			[2,3]			
$NP \rightarrow I / she / me$						
$NP \rightarrow TWA \ / Houston$						
$NP \rightarrow Det Nominal$						
Nominal $\rightarrow$ book   flight   meal   money	- T					
Nominal → Nominal Noun	Lexicon					
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that \mid this \mid a$					
$VP \rightarrow book \ / \ include \ / \ prefer$	- Noun $\rightarrow$ book   flight   meal	money				
$VP \rightarrow Verb NP$	$Pronoun \rightarrow I \mid she \mid me$					
$VP \rightarrow X2 PP$	$Proper-Noun \rightarrow Houston \mid$	I WA				
$X2 \rightarrow Verb NP$	$Aux \rightarrow does$					
$VP \rightarrow Verb PP$	$Preposition \rightarrow from \mid to \mid o$ $Varb \rightarrow back \mid in all da \mid nucleoned$					
$VP \rightarrow VP PP$	$Verb \rightarrow book \mid include \mid pre$	161.				
$PP \rightarrow Preposition NP$						
	brefer a	flight	on	TWA		
	projet a	Ingitt	UIT			
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						NIVERSITY of WASHINGTON



Q. Crommor						
$\mathscr{L}_1 \operatorname{Grammar}_{S \to NP \ VP}$	NP, Pronoun	S				
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]			
$X1 \rightarrow Aux NP$			[0,5]			
$S \rightarrow book \ / \ include \ / \ prefer$		Verb, VP, S				
$S \rightarrow Verb NP$		[1,2]	[1,3]			
$S \rightarrow X2 PP$						
$S \rightarrow Verb PP$			Det			
$S \rightarrow VP PP$			[2,3]			
$NP \rightarrow I / she / me$			[_,]			
$NP \rightarrow TWA / Houston$						
$NP \rightarrow Det Nominal$						
$Nominal \rightarrow book   flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book   include   prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition Ni$	<b>Lexicon</b> $Det \rightarrow that   this   a$ $Noun \rightarrow book   flight   meal$ $Pronoun \rightarrow I   she   me$ $Proper-Noun \rightarrow Houston   'A$ $Aux \rightarrow does$ $Preposition \rightarrow from   to   on$ $Verb \rightarrow book   include   pref$	$\Gamma WA$ $n \mid near \mid through$	h			
	prefer a	flight	on	TWA		
	2 3		4	5	6 <b>W</b> U	NIVERSITY of WASHING



$\mathcal{L}_1 \operatorname{\mathbf{Grammar}}_{S \to NP \ VP}$	NP, Pronoun	S				
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]			
$X1 \rightarrow Aux NP$						
$S \rightarrow book \   \ include \   \ prefer$		Verb, VP, S				
$S \rightarrow Verb NP$		[1,2]	[1,3]			
$S \rightarrow X2 PP$						
$S \rightarrow Verb PP$			Det			
$S \rightarrow VP PP$			[2,3]			
$NP \rightarrow I / she / me$			L / J			
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$						
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon					
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid meal$	moneu				
$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	<i>11001009</i>				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 2$	ΓWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					
$X2 \rightarrow Verb NP$	Preposition $\rightarrow$ from   to   or	$n \mid near \mid through$	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pref$					
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition N$	C	0.1.				
1	brefer a	flight	on	TWA		
0	2 3		4	5	6	



$\mathscr{L}_1$ Grammar	
$S \rightarrow NP VP$	
$S \rightarrow X1 VP$	
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	-
$NP \rightarrow TWA / Houston$	
$NP \rightarrow Det Nominal$	
<i>Nominal</i> → <i>book</i> / <i>flight</i> / <i>meal</i> / <i>money</i>	-
Nominal → Nominal Noun	
$Nominal \rightarrow Nominal PP$	
$VP \rightarrow book \ / \ include \ / \ prefer$	
$VP \rightarrow Verb NP$	
$VP \rightarrow X2 PP$	
$X2 \rightarrow Verb NP$	
$VP \rightarrow Verb PP$	
$VP \rightarrow VP PP$	
$PP \rightarrow Preposition NP$	-
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# NP, Pronoun [0,1]

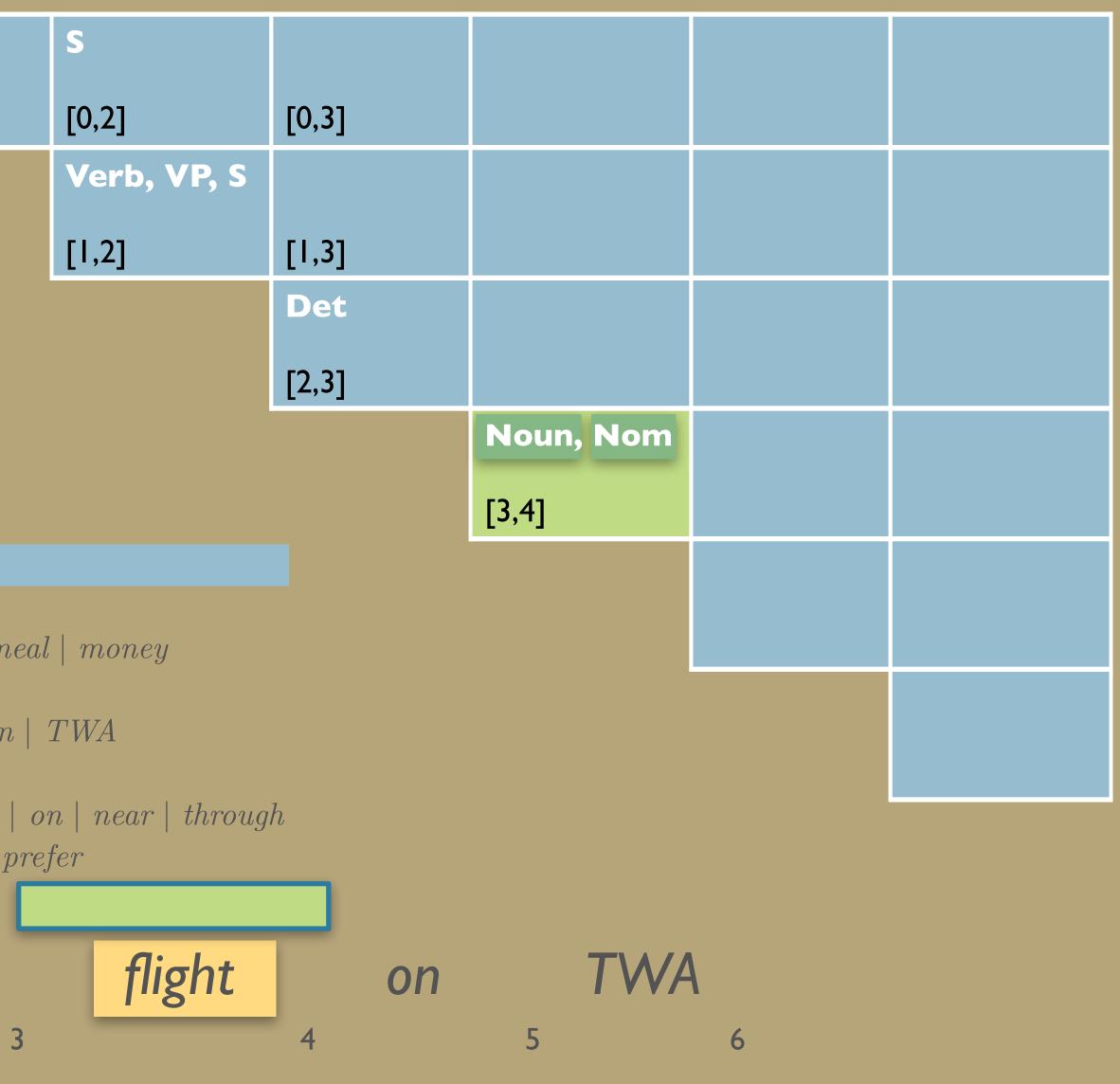
### Lexicon

 $\begin{array}{l} Det \rightarrow that \mid this \mid a \\ \hline Noun \rightarrow book \mid flight \mid meal \mid money \\ Pronoun \rightarrow I \mid she \mid me \\ Proper-Noun \rightarrow Houston \mid TWA \\ Aux \rightarrow does \\ Preposition \rightarrow from \mid to \mid on \mid near \mid through \\ Verb \rightarrow book \mid include \mid prefer \end{array}$ 

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$\mathscr{L}_1$ Grammar
$S \rightarrow NP VP$
$S \rightarrow X1 VP$
$X1 \rightarrow Aux NP$
$S \rightarrow book \mid include \mid prefer$
$S \rightarrow Verb NP$
$S \rightarrow X2 PP$
$S \rightarrow Verb PP$
$S \rightarrow VP PP$
$NP \rightarrow I / she / me$
$NP \rightarrow TWA / Houston$
$NP \rightarrow Det Nominal$
Nominal $\rightarrow$ book / flight / meal / money
Nominal → Nominal Noun
$Nominal \rightarrow Nominal PP$
$VP \rightarrow book \ / \ include \ / \ prefer$
$VP \rightarrow Verb NP$
$VP \rightarrow X2 PP$
$X2 \rightarrow Verb NP$
$VP \rightarrow Verb PP$
$VP \rightarrow VP PP$
$PP \rightarrow Preposition NP$
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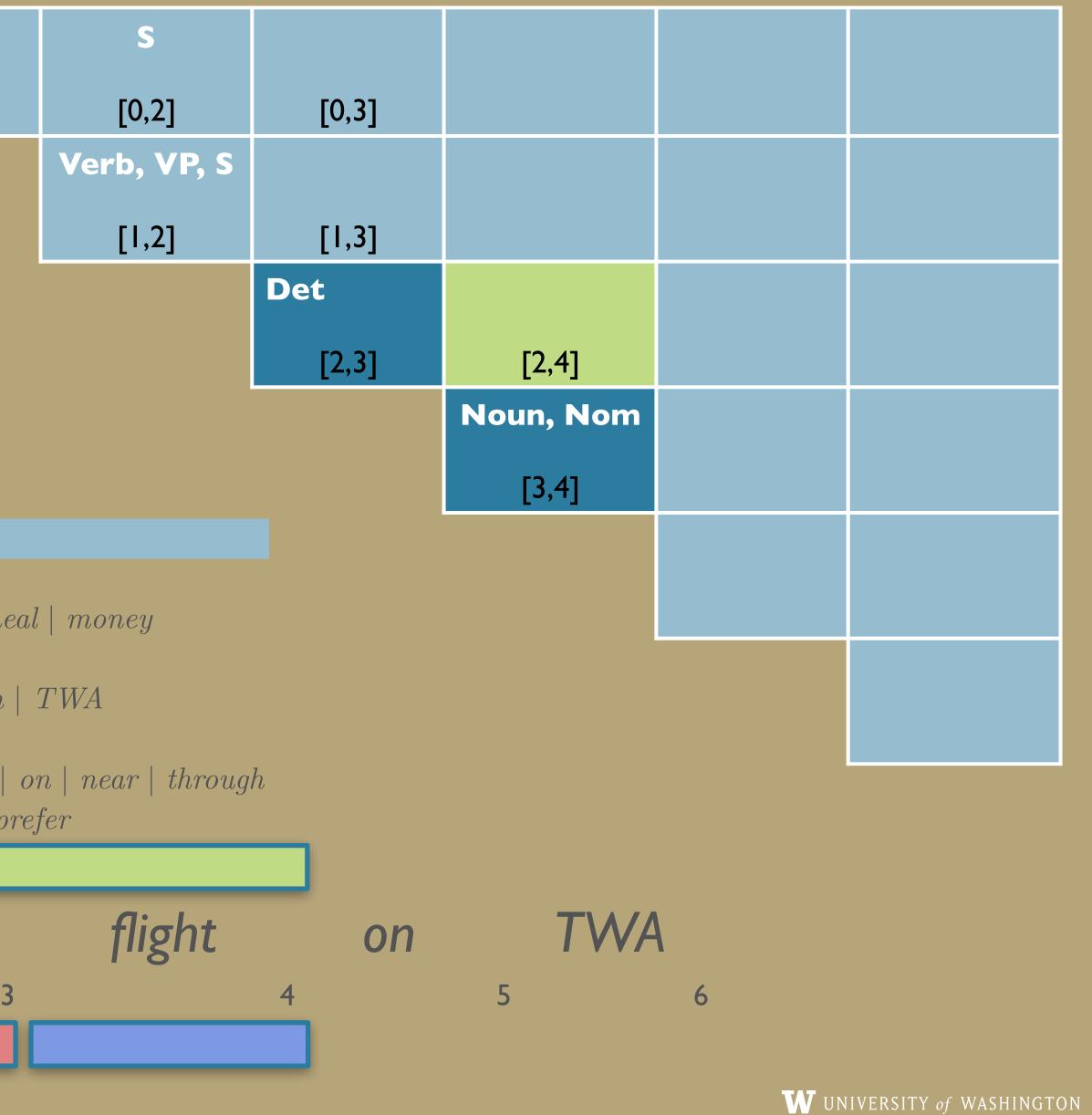
## NP, Pronoun [0,1]

#### Lexicon

 $\begin{array}{l} Det \rightarrow that \mid this \mid a \\ Noun \rightarrow book \mid flight \mid meal \mid money \\ Pronoun \rightarrow I \mid she \mid me \\ Proper-Noun \rightarrow Houston \mid TWA \\ Aux \rightarrow does \\ Preposition \rightarrow from \mid to \mid on \mid near \mid through \\ Verb \rightarrow book \mid include \mid prefer \end{array}$ 



а





# $\mathscr{L}_1$ Grammar $S \rightarrow NP VP$ $S \rightarrow X1 VP$ $X1 \rightarrow Aux NP$ $S \rightarrow book \ | \ include \ | \ prefer$ $S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I / she / me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ Nominal $\rightarrow$ book | flight | meal | money Nominal → Nominal Noun $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \ | \ include \ | \ prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$

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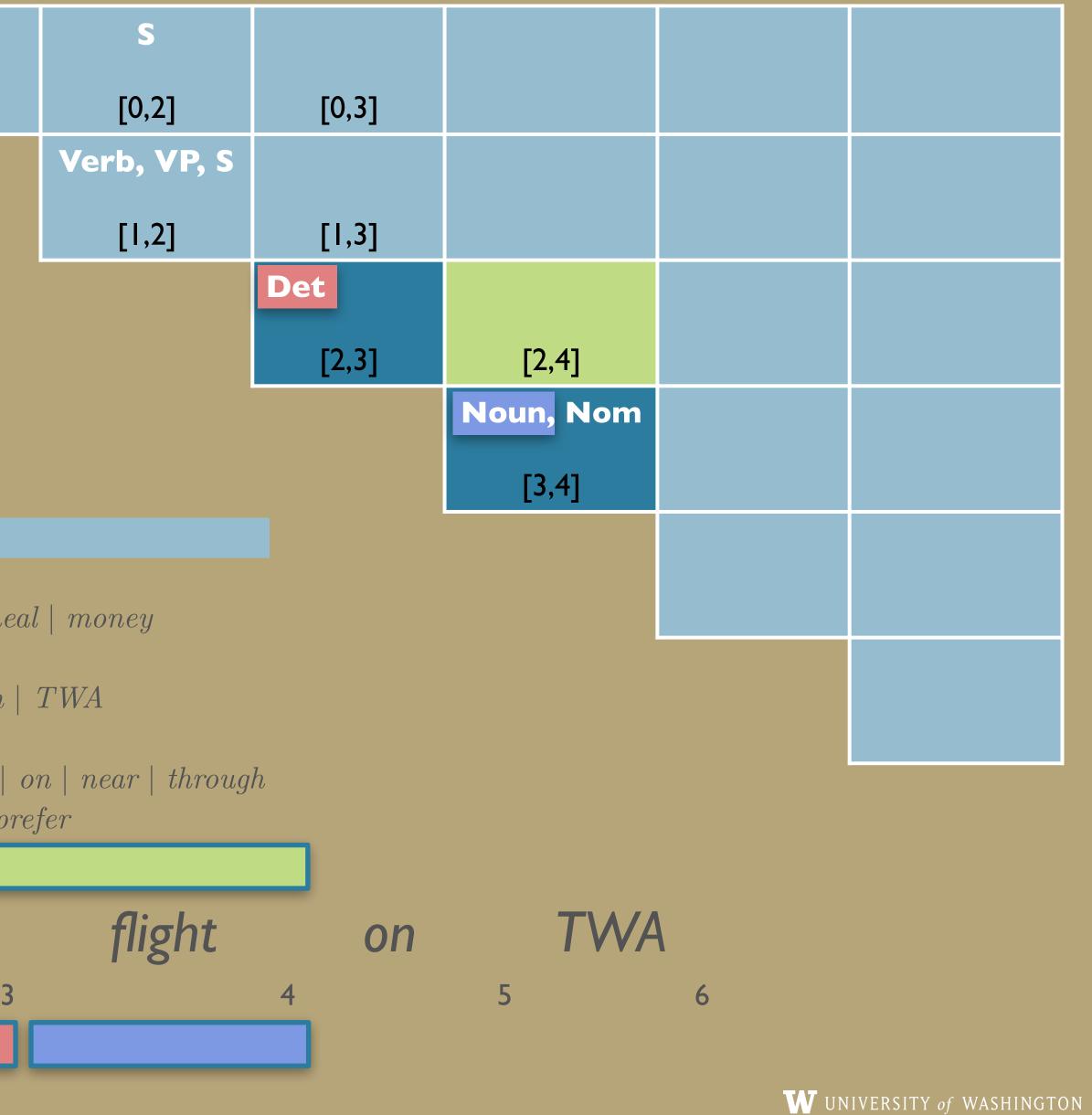
## NP, Pronoun [0,1]

#### Lexicon

 $\begin{array}{l} Det \rightarrow that \mid this \mid a \\ Noun \rightarrow book \mid flight \mid meal \mid money \\ Pronoun \rightarrow I \mid she \mid me \\ Proper-Noun \rightarrow Houston \mid TWA \\ Aux \rightarrow does \\ Preposition \rightarrow from \mid to \mid on \mid near \mid through \\ Verb \rightarrow book \mid include \mid prefer \end{array}$ 



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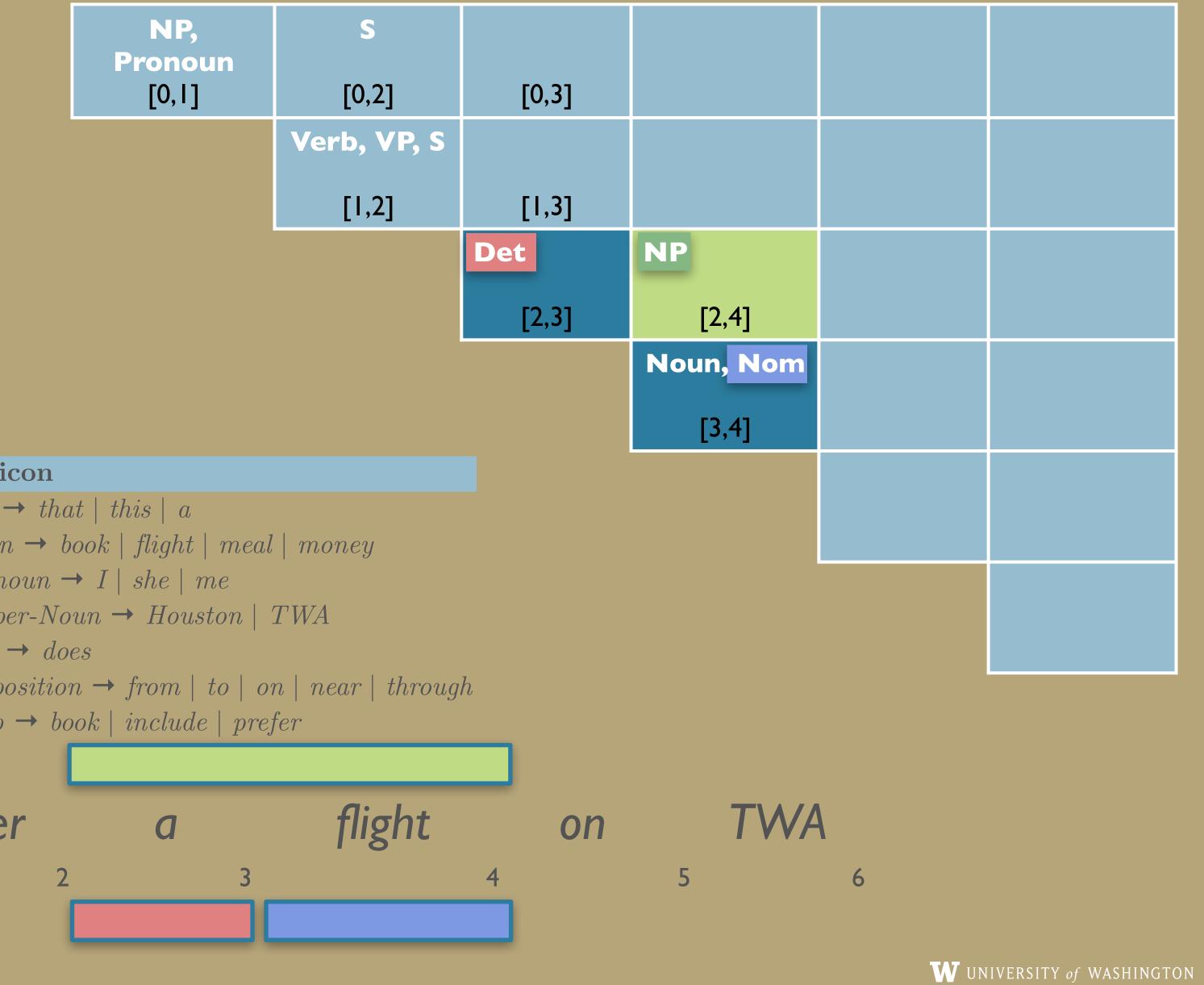
$\mathcal{Q}_{1}$ Grammar $S \rightarrow NP VP$ $S \rightarrow NP VP$ $S \rightarrow X1 VP$ $X1 \rightarrow Aux NP$ $S \rightarrow book   include   prefer$ $S \rightarrow Verb NP$ $S \rightarrow Verb PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow TWA   Houston$ $NP \rightarrow TWA   Houston$ $NP \rightarrow Det Nominal$ Nominal $\rightarrow book   flight   meal   money$ Nominal $\rightarrow book   flight   meal   money$ Nominal $\rightarrow Nominal Noun$ Nominal $\rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $VP \rightarrow VPPP$ $PP \rightarrow Preposition NP$ Image: Description of the preferic of		
$S \rightarrow X1 \ VP$ $X1 \rightarrow Aux \ NP$ $S \rightarrow book \   \ include \   \ prefer$ $S \rightarrow Verb \ NP$ $S \rightarrow Verb \ PP$ $S \rightarrow Verb \ PP$ $NP \rightarrow I \   \ she \   \ me$ $NP \rightarrow TWA \   \ Houston$ $NP \rightarrow Det \ Nominal$ $Nominal \rightarrow book \   \ flight \   \ meal \   \ money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \   \ include \   \ prefer$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$	$\mathscr{L}_1$ Grammar	
$X1 \rightarrow Aux NP$ $S \rightarrow book / include / prefer$ $S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow Verb PP$ $NP \rightarrow I / she / me$ $NP \rightarrow TWA / Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book / flight / meal / money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book / include / prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $VP \rightarrow PP$	$S \rightarrow NP VP$	
$S \rightarrow book \mid include \mid prefer$ $S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det \mid Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $PP \rightarrow Preposition NP$	$S \rightarrow X1 VP$	
$S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $VP \rightarrow Preposition NP$	$X1 \rightarrow Aux NP$	
$S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I / she / me$ $NP \rightarrow TWA / Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book / flight / meal / money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book / include / prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $Preposition NP$	$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$	$S \rightarrow Verb NP$	
$S \rightarrow VP PP$ $NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det \mid Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal \mid Noun$ $Nominal \rightarrow Nominal \mid PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb \mid NP$ $VP \rightarrow Verb \mid NP$ $VP \rightarrow Verb \mid NP$ $VP \rightarrow Verb \mid PP$ $VP \rightarrow Verb \mid PP$ $VP \rightarrow Verb \mid PP$ $VP \rightarrow VP \mid PP$ $PP \rightarrow Preposition \mid NP$	$S \rightarrow X2 PP$	
$NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det \mid Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$ $Nominal \rightarrow Nominal \mid Noun$ $Nominal \rightarrow Nominal \mid PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb \mid NP$ $VP \rightarrow Verb \mid NP$ $VP \rightarrow Verb \mid NP$ $VP \rightarrow Verb \mid PP$ $VP \rightarrow Verb \mid PP$ $VP \rightarrow Verb \mid PP$ $VP \rightarrow VP \mid PP$ $PP \rightarrow Preposition \mid NP$	$S \rightarrow Verb PP$	
$NP \rightarrow TWA / Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book / flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book   include   prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$	$S \rightarrow VP PP$	
$NP \rightarrow Det Nominal$ $Nominal \rightarrow book   flight   meal   money$ $Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book   include   prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow Verb PP$ $PP \rightarrow Preposition NP$	$NP \rightarrow I / she / me$	
Nominal $\rightarrow$ book / flight / meal / moneyLetNominal $\rightarrow$ Nominal NounDetNominal $\rightarrow$ Nominal PPDetNoNoVP $\rightarrow$ book / include / preferProVP $\rightarrow$ Verb NPProVP $\rightarrow$ X2 PPAuxX2 $\rightarrow$ Verb NPProVP $\rightarrow$ Verb PPProVP $\rightarrow$ VP PPProPP $\rightarrow$ Preposition NP	$NP \rightarrow TWA \mid Houston$	
Nominal $\rightarrow$ Nominal NounDefinitionNominal $\rightarrow$ Nominal PPDefinition $VP \rightarrow$ book / include / preferNor $VP \rightarrow$ Verb NPPrefer $VP \rightarrow$ X2 PPAutorX2 $\rightarrow$ Verb NPPrefer $VP \rightarrow$ Verb PPPrefer $VP \rightarrow$ VP PPPreposition NP	$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ Nominal NounDefinitionNominal $\rightarrow$ Nominal PPDefinition $VP \rightarrow$ book / include / preferNot $VP \rightarrow$ Verb NPPrefer $VP \rightarrow$ X2 PPAutorX2 $\rightarrow$ Verb NPPrefer $VP \rightarrow$ Verb PPVerb Verb $VP \rightarrow$ VP PPVerb	Nominal $\rightarrow$ book   flight   meal   money	Los
Nominal $\rightarrow$ Nominal PPNor $VP \rightarrow book \mid include \mid prefer$ $Prefer$ $VP \rightarrow Verb NP$ $Prefer$ $VP \rightarrow X2 PP$ $Aux$ $X2 \rightarrow Verb NP$ $Prefer$ $VP \rightarrow Verb PP$ $Prefer$ $VP \rightarrow VP PP$ $Prefer$ $PP \rightarrow Preposition NP$ $Prefer$	Nominal → Nominal Noun	
$VP \rightarrow book \   \ include \   \ prefer$ $VP \rightarrow Verb \ NP$ $VP \rightarrow X2 \ PP$ $X2 \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$ $VP \rightarrow Verb \ PP$ $Preposition \ NP$ $Preposition \ NP$	$Nominal \rightarrow Nominal PP$	
$VP \rightarrow Verb NP$ $VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$ $Pre$	$VP \rightarrow book \ / \ include \ / \ prefer$	
$VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$ $Aux$ $Pre$ $Vre$	$VP \rightarrow Verb NP$	_
$\begin{array}{l} X2 \rightarrow Verb \ NP \\ VP \rightarrow Verb \ PP \\ VP \rightarrow VP \ PP \\ PP \rightarrow Preposition \ NP \end{array} \begin{array}{l} Pre \\ Ver \\ Ver \\ PP \end{array}$	$VP \rightarrow X2 PP$	
$VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$	$X2 \rightarrow Verb NP$	_
$VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$	$VP \rightarrow Verb PP$	Ver
	$VP \rightarrow VP PP$	101
l pref	$PP \rightarrow Preposition NP$	
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NP, Pronoun [0,1]

#### icon

 $\rightarrow$  that | this | a  $n \rightarrow book \mid flight \mid meal \mid money$  $noun \rightarrow I \mid she \mid me$  $per-Noun \rightarrow Houston \mid TWA$  $\rightarrow$  does  $\rightarrow$  book | include | prefer



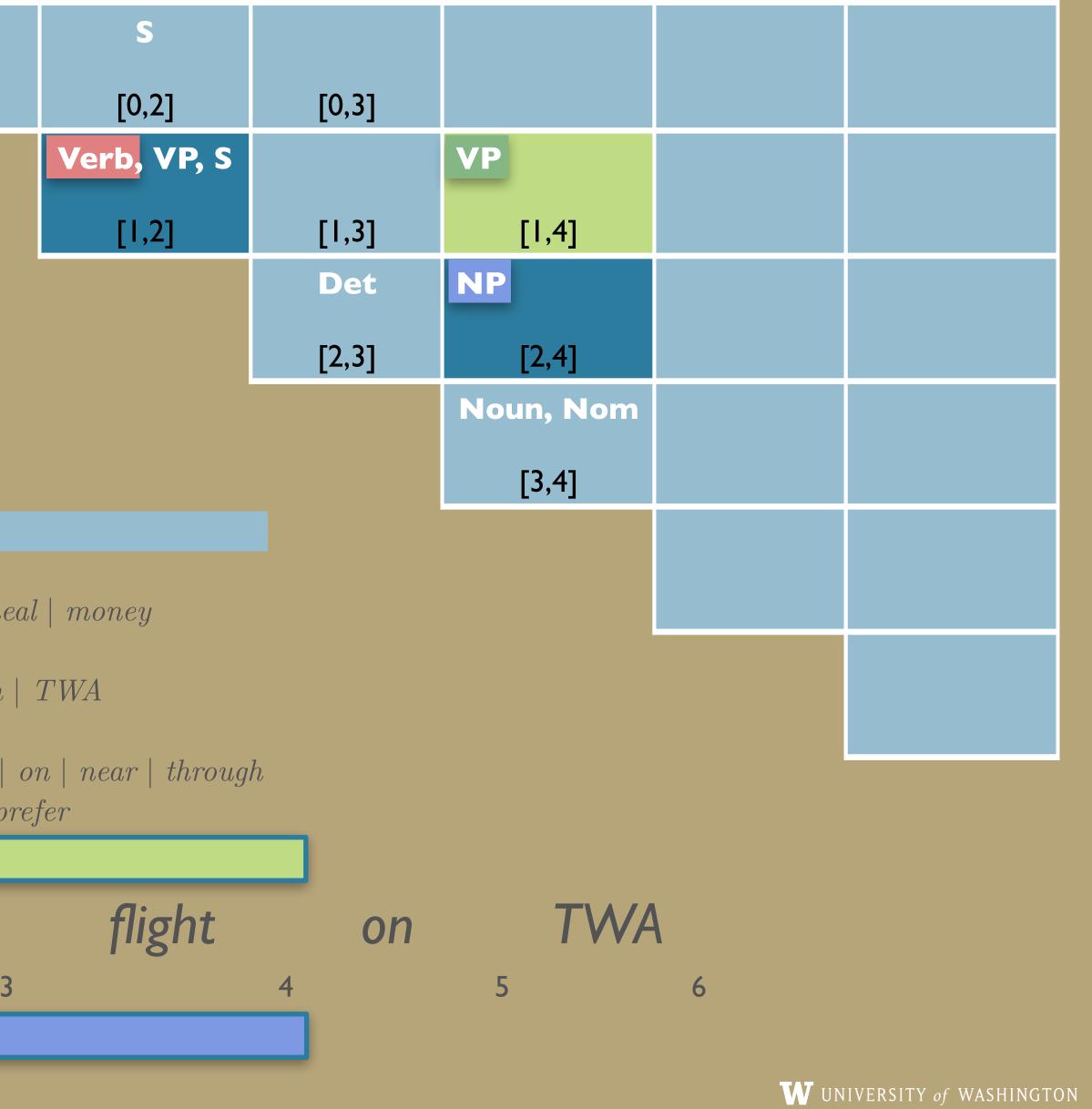




$\mathscr{L}_1$ Grammar	NP,	S				
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]			
$X1 \rightarrow Aux NP$		Verb, VP, S				
$S \rightarrow book \ / \ include \ / \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]		
$S \rightarrow X2 PP$			Det	NP		
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]		
$NP \rightarrow I / she / me$				Noun, Nom		
$NP \rightarrow TWA \mid Houston$				,,		
$NP \rightarrow Det Nominal$				[3,4]		
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon					
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	Noun $\rightarrow$ book   flight   meal	money				
$VP \rightarrow book \   \ include \   \ prefer$	$Pronoun \rightarrow I \mid she \mid me$					
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 1$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid or$	$n \mid near \mid through$	$\dot{\imath}$			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid prej$					
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$						
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$\mathscr{L}_1$ Grammar	NP,
$S \rightarrow NP VP$	Pronoun
$S \rightarrow X1 \ VP$	[0,1]
$X1 \rightarrow Aux NP$	
$S \rightarrow book \ / \ include \ / \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
$NP \rightarrow TWA / Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book / flight / meal / money	
$Nominal \rightarrow Nominal Noun$	Lexicon
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that \mid this \mid a$
$VP \rightarrow book \ / \ include \ / \ prefer$	$\cdots \cdots \qquad Noun \rightarrow book \mid flight \mid mea$
$VP \rightarrow Verb NP$	$Pronoun \rightarrow I \mid she \mid me$
$VP \rightarrow X2 PP$	$Proper-Noun \rightarrow Houston \mid$
$\begin{array}{cccc} & & & & \\ & & & \\ & X2 \rightarrow & Verb & NP \end{array}$	$Aux \rightarrow does$
	$Preposition \rightarrow from \mid to \mid d$
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pre$
$VP \rightarrow VP PP$	
$PP \rightarrow Preposition NP$	
	prefer a
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$\mathscr{L}_1$ Grammar	NP,	S				
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]			
$X1 \rightarrow Aux NP$		Verb, VP, S		<b>VP, X2</b>		
$S \rightarrow book \ / \ include \ / \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]		
$S \rightarrow X2 PP$			Det	NP		
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]		
$NP \rightarrow I / she / me$				Noun, Nom		
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]		
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon			L / J		
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid meal$	moneu				
$VP \rightarrow book \   \ include \   \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	n monocy				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid o$	n   near   throual	h.			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pre$		U			
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$						
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$\mathscr{L}_1$ Grammar	NP,	S				
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 \ VP$	[0,1]	[0,2]	[0,3]			
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		
$S \rightarrow book \   \ include \   \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]		
$S \rightarrow X2 PP$			Det	NP		
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]		
$NP \rightarrow I / she / me$				Noun, Nom		
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]		
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon					
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	Noun $\rightarrow$ book   flight   meal	money				
$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow I \mid she \mid me$					
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 1$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid ot$	$n \mid near \mid through$	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pres$	fer				
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$		a				
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$\mathscr{L}_1$ Grammar	NP,	S				
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]			
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		
$S \rightarrow book \   \ include \   \ prefer$				· · · <b>,</b> · · · <b>,</b> · · · <b>,</b> ·		
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]		
$S \rightarrow X2 PP$			Det	NP		
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]		
$NP \rightarrow I / she / me$			L / J			
$NP \rightarrow TWA \mid Houston$				Noun, Nom		
$NP \rightarrow Det Nominal$				[3,4]		
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon					
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid meal$	ี moneu				
$VP \rightarrow book \   \ include \   \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	Intoricg				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid o$	n   near   through	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pre$		U			
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$						
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$\mathscr{L}_1$ Grammar	NP,	S				
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]			
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		
$S \rightarrow book \ / \ include \ / \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]		
$S \rightarrow X2 PP$			Det	NP		
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]		
$NP \rightarrow I / she / me$				Noun, Nom		
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]		
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon					
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid meal$	moneu				
$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	<i>1101009</i>				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 1$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid or$	n   near   throuai	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pres$		U			
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$						
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$\mathscr{L}_1$ Grammar	NP,	S				
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]			
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		
$S \rightarrow book \ / \ include \ / \ prefer$				,, .		
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]		
$S \rightarrow X2 PP$			Det	NP		
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]		
$NP \rightarrow I / she / me$			L / J			
$NP \rightarrow TWA \mid Houston$				Noun, Nom		
$NP \rightarrow Det Nominal$				[3,4]		
Nominal $\rightarrow$ book / flight / meal / money	Lexicon					
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid meal$	1 moneu				
$VP \rightarrow book \   \ include \   \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	monocy				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 1$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid or$	n   near   throual	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid president$		U			
$VP \rightarrow VP PP$			_			
$PP \rightarrow Preposition NP$						
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$\mathscr{L}_1$ Grammar	NP,	S				
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]			
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		
$S \rightarrow book \ / \ include \ / \ prefer$				, , , , , , , , , , , , , , , , , , ,		
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]		
$S \rightarrow X2 PP$			Det	NP		
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]		
$NP \rightarrow I / she / me$						
$NP \rightarrow TWA \mid Houston$				Noun, Nom		
$NP \rightarrow Det Nominal$				[3,4]		
Nominal $\rightarrow$ book / flight / meal / money	Lexicon					
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid meal$	1 moneu				
$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	nooneg				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 2$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid or$	n   near   through	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid president$		0			
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$						
	prefer a	flight	on	TWA		
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	2 3			5	6	
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$\mathscr{L}_1$ Grammar		NP,
$S \rightarrow NP VP$		Pronoun
$S \rightarrow X1 VP$		[0,1]
$X1 \rightarrow Aux NP$		
$S \rightarrow book \ / \ include \ / \ prefer$		
$S \rightarrow Verb NP$		
$S \rightarrow X2 PP$		
$S \rightarrow Verb PP$		
$S \rightarrow VP PP$		
$NP \rightarrow I / she / me$		
$NP \rightarrow TWA / Houston$		
$NP \rightarrow Det Nominal$		
Nominal $\rightarrow$ book / flight / meal / money		
$Nominal \rightarrow Nominal Noun$	Lexicon	
$Nominal \rightarrow Nominal PP$		$at \mid this \mid a$
$VP \rightarrow book \ / \ include \ / \ prefer$		$pook \mid flight \mid me$
$VP \rightarrow Verb NP$	Pronoun -	$\rightarrow I \mid she \mid me$
$VP \rightarrow X2 PP$	Proper-No	$oun \rightarrow Houston$
$\begin{array}{cccc} & & & & \\ & & & \\ & X2 \rightarrow & Verb \ NP \end{array}$	$Aux \rightarrow do$	es
$VP \rightarrow Verb PP$	Prepositio	$n \rightarrow from \mid to \mid$
	$Verb \rightarrow bc$	$pok \mid include \mid p_i$
$VP \rightarrow VP PP$		
$PP \rightarrow Preposition \Lambda$		
	prefer	a
0	2	3

	S								
	[0,2]	[0,3]		[0,4]					
	Verb, VP, S			VP, X	(2, S				
	[1,2]	[1,3]		[1,4]					
		Det		NP					
		[2,3]		[2,4]					
				Noun	, Nom				
				[3,4]					
real	money								
n   '	ΓWA								
01 prej	n   near   throug <sup>f</sup> er	h							
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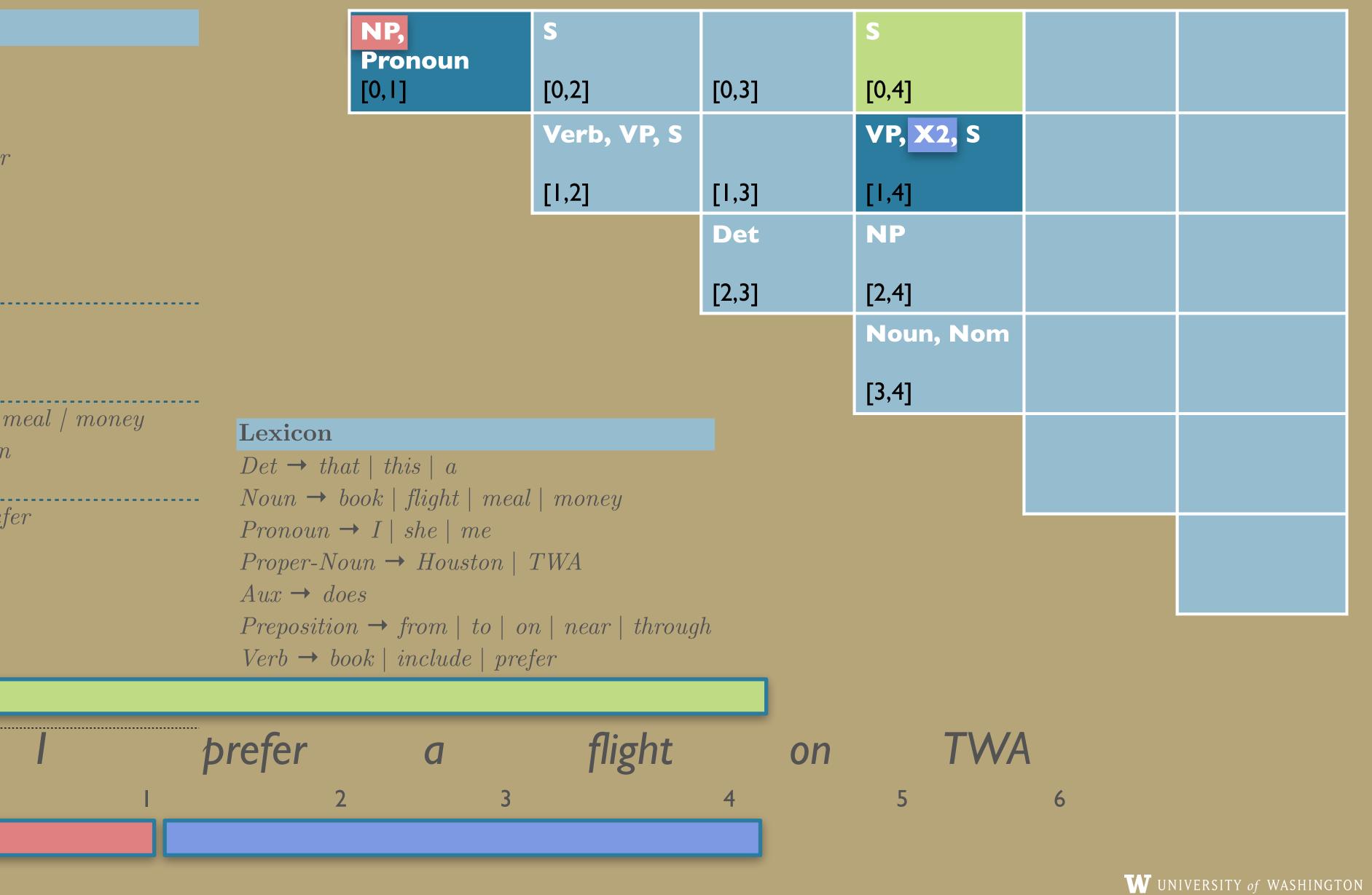
$\mathscr{L}_1$ Grammar	NP,	S		S	
$S \rightarrow NP VP$	Pronoun				
$S \rightarrow X1 \ VP$	[0,1]	[0,2]	[0,3]	[0,4]	
$X1 \rightarrow Aux NP$		Verb, VP, S		<b>VP, X2, S</b>	
$S \rightarrow book \ / \ include \ / \ prefer$					
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	
$S \rightarrow X2 PP$			Det	NP	
$S \rightarrow Verb PP$					
$S \rightarrow VP PP$			[2,3]	[2,4]	
$NP \rightarrow I / she / me$				Noun, Nom	
$NP \rightarrow TWA \mid Houston$					
$NP \rightarrow Det Nominal$				[3,4]	
$Nominal \rightarrow book \   \ flight \   \ meal \   \ money$	Lexicon				
Nominal - Nominal Noun					
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that \mid this \mid a$				
$VP \rightarrow book \ / \ include \ / \ prefer$	$Noun \rightarrow book \mid flight \mid meal$	t   money			
$VP \rightarrow Verb NP$	$Pronoun \rightarrow I \mid she \mid me$				
$VP \rightarrow X2 PP$	$Proper-Noun \rightarrow Houston \mid$	I WA			
$X2 \rightarrow Verb NP$	$Aux \rightarrow does$		1		
$VP \rightarrow Verb PP$	$Preposition \rightarrow from \mid to \mid o$		n N		
$VP \rightarrow VP PP$	$Verb \rightarrow book \mid include \mid pre$	Jer			
$PP \rightarrow Preposition \Lambda$					
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$\mathscr{L}_1$ Grammar			
$S \rightarrow NP VP$			
$S \rightarrow X1 VP$			
$X1 \rightarrow Aux NP$			
$S \rightarrow book \ / \ include \ /$	prefer		
$S \rightarrow Verb NP$			
$S \rightarrow X2 PP$			
$S \rightarrow Verb PP$			
$S \rightarrow VP PP$			
$NP \rightarrow I \mid she \mid me$			
$NP \rightarrow TWA \mid Hous$	ton		
$NP \rightarrow Det Nominal$			
$Nominal \rightarrow book \ / fl$	light   mea	al / money	Lexico
Nominal - Nomina	al Noun		
Nominal - Nomina	l PP		$Det \rightarrow$
$VP \rightarrow book \ / \ include$	e   prefer		Noun -
$VP \rightarrow Verb NP$	,		Pronou
$VP \rightarrow X2 PP$			Proper-
$X2 \rightarrow Verb NP$			$Aux \rightarrow D$
$VP \rightarrow Verb PP$			Prepose Verb
$VP \rightarrow VP PP$			$Verb \rightarrow$
$PP \rightarrow Preposition I$	v 4		
			prefer
			prejer
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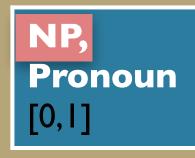


 $un \rightarrow I \mid she \mid me$ does

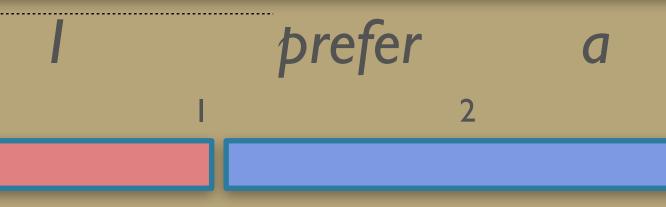




$\mathscr{L}_1$ Grammar			
$S \rightarrow NP VP$			
$S \rightarrow X1 VP$			
$X1 \rightarrow Aux NP$			
$S \rightarrow book \ / \ include \ /$	prefer		
$S \rightarrow Verb NP$			
$S \rightarrow X2 PP$			
$S \rightarrow Verb PP$			
$S \rightarrow VP PP$			
$NP \rightarrow I \mid she \mid me$			
$NP \rightarrow TWA \mid Hous$	ton		
$NP \rightarrow Det Nominal$			
$Nominal \rightarrow book \ / fl$	light   mea	al / money	Lexico
Nominal - Nomina	l Noun		
Nominal - Nomina	l PP		$Det \rightarrow$
$VP \rightarrow book \ / \ include$	e   prefer		Noun -
$VP \rightarrow Verb NP$	,		Pronou
$VP \rightarrow X2 PP$			Proper-
$X2 \rightarrow Verb NP$			$Aux \rightarrow D$
$VP \rightarrow Verb PP$			Prepose Venh
$VP \rightarrow VP PP$			$Verb \rightarrow$
$PP \rightarrow Preposition I$	v 4		
			prefer
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• that | this | a • book | flight | me oun  $\rightarrow I$  | she | me r-Noun  $\rightarrow$  Houston does sition  $\rightarrow$  from  $\mid$  to  $\mid$  $\rightarrow$  book | include |



	S			S					
	[0,2]	[0,3]		[0,4]					
	Verb, VP, S			VP, X	(2, S				
	[1,2]	[1,3]		[1,4]					
		Det		NP					
		[2,3]		[2,4]					
				Noun	, Nom				
				[3,4]					
real	money								
$n \mid 2$	TWA								
or prej	n   near   throug <sup>f</sup> er	h							
-	<i>a</i>	_							
	flight		on		TWA				
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$\mathscr{L}_1$ Grammar				NP,
$S \rightarrow NP VP$				Pronoun
$S \rightarrow X1 VP$				0,1]
$X1 \rightarrow Aux NP$				
$S \rightarrow book \   \ include \  $	<sup> </sup> prefer			
$S \rightarrow Verb NP$				
$S \rightarrow X2 PP$				
$S \rightarrow Verb PP$				
$S \rightarrow VP PP$				
$NP \rightarrow I / she / me$			•	
$NP \rightarrow TWA \mid Hous$	ton			
$NP \rightarrow Det Nominal$				
$Nominal \rightarrow book \mid fi$ $Nominal \rightarrow Nomina$ $Nominal \rightarrow Nomina$ $VP \rightarrow book \mid includ$ $VP \rightarrow Verb \ NP$ $VP \rightarrow X2 \ PP$ $X2 \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$ $VP \rightarrow VP \ PP$	el Noun el PP	/ money	$Pronoun \rightarrow$ $Proper-Nout$ $Aux \rightarrow does$ $Preposition$	$bk \mid flight \mid mean of I \mid she \mid mean of Mouston \mid flight \mid mean of Mouston \mid for the second second$
$PP \rightarrow Preposition I$	· -			
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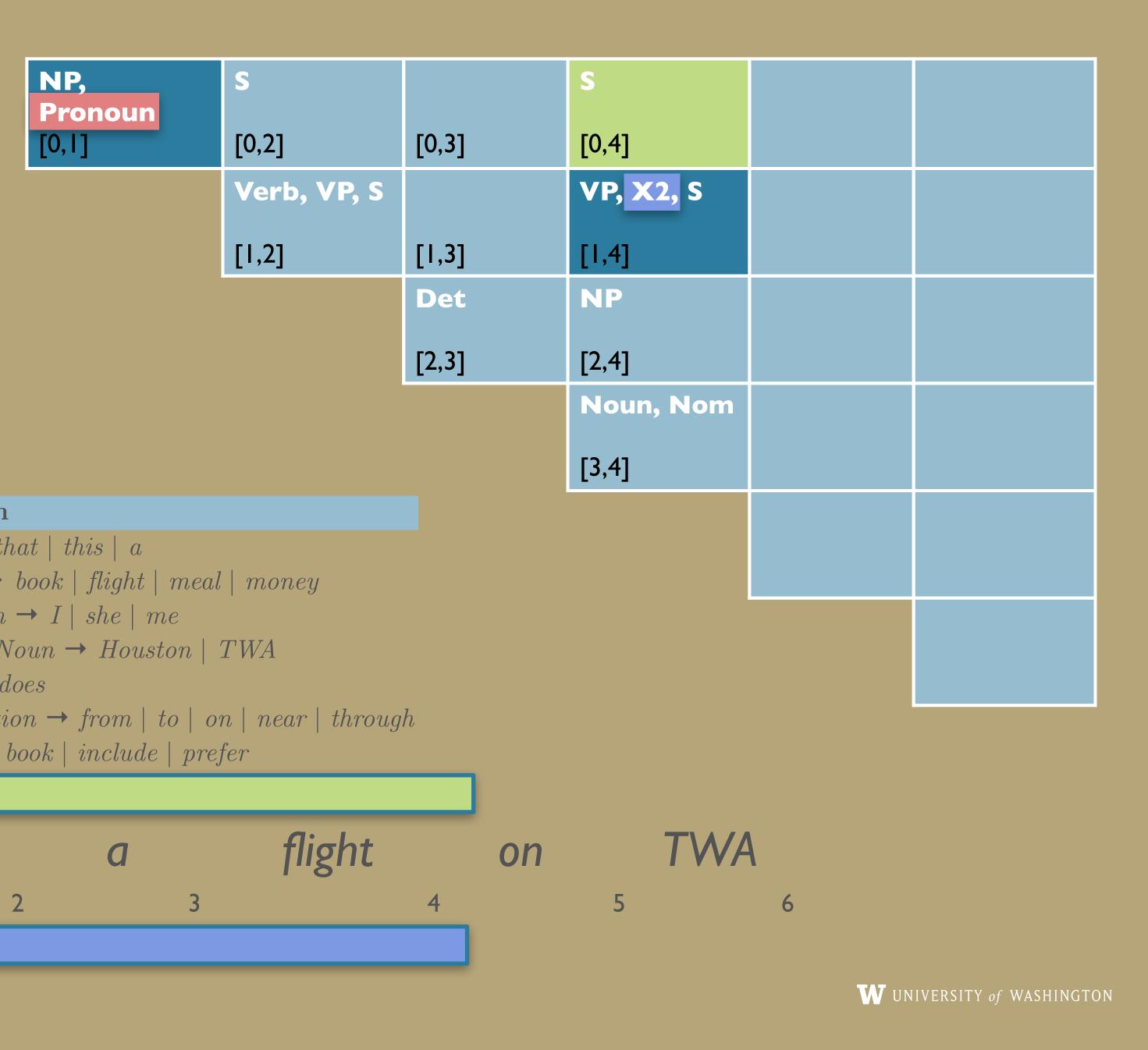
	S			S					
	[0,2]	[0,3]		[0,4]					
	Verb, VP, S			VP, X	2, S				
	[1,2]	[1,3]		[1,4]					
		Det		NP					
		[2,3]		[2,4]					
				Noun	, Nom				
				[3,4]					
real	money								
$n \mid 2$	ΓWA								
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$\mathscr{L}_1$ Grammar	N
$S \rightarrow NP VP$	P
$S \rightarrow X1 \ VP$	[0
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
$NP \rightarrow TWA \mid Houston$	
$NP \rightarrow Det Nominal$	
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$	Lexicon
Nominal → Nominal Noun	$Det \rightarrow that \mid$
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book$
$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow 1$
$VP \rightarrow Verb NP$	Proper-Noun
$VP \rightarrow X2 PP$	$Aux \rightarrow does$
$X2 \rightarrow Verb NP$	Preposition –
$VP \rightarrow Verb PP$	$Verb \rightarrow book$
$VP \rightarrow VP PP$	VETU VOUN
$PP \rightarrow Preposition I$	
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NP,

[0,1]



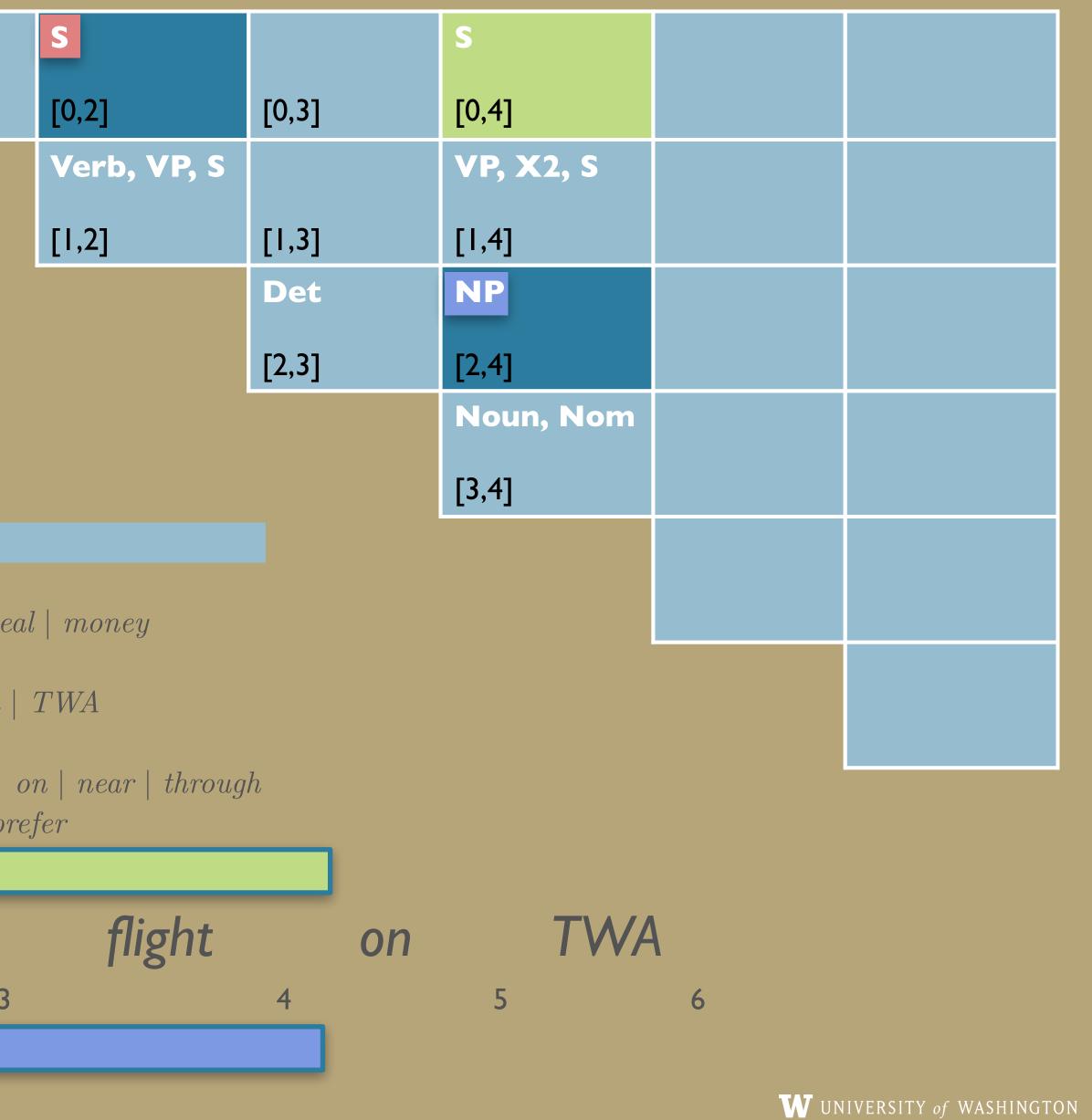


$\mathscr{L}_1$ Grammar				NP,
$S \rightarrow NP VP$				Pronoun
$S \rightarrow X1 VP$				0,1]
$X1 \rightarrow Aux NP$				
$S \rightarrow book \   \ include \  $	<sup> </sup> prefer			
$S \rightarrow Verb NP$				
$S \rightarrow X2 PP$				
$S \rightarrow Verb PP$				
$S \rightarrow VP PP$				
$NP \rightarrow I / she / me$			•	
$NP \rightarrow TWA \mid Hous$	ton			
$NP \rightarrow Det Nominal$				
$Nominal \rightarrow book \mid fi$ $Nominal \rightarrow Nomina$ $Nominal \rightarrow Nomina$ $VP \rightarrow book \mid includ$ $VP \rightarrow Verb \ NP$ $VP \rightarrow X2 \ PP$ $X2 \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$ $VP \rightarrow VP \ PP$	el Noun el PP	/ money	$Pronoun \rightarrow$ $Proper-Nout$ $Aux \rightarrow does$ $Preposition$	$bk \mid flight \mid mean of I \mid she \mid mean of Mouston \mid flight \mid mean of Mouston \mid for the second second$
$PP \rightarrow Preposition I$	· -			
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	S			S					
	[0,2]	[0,3]		[0,4]					
	Verb, VP, S			VP, X	2, S				
	[1,2]	[1,3]		[1,4]					
		Det		NP					
		[2,3]		[2,4]					
				Noun	, Nom				
				[3,4]					
real	money								
$n \mid 2$	TWA								
oı prej	n   near   throug <sup>f</sup> er	h							
-	<u><u>a:</u> _1, ,</u>	_			<b>T\</b>				
	flight		on		TWA				
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$\mathscr{L}_1$ Grammar	NP,
$S \rightarrow NP VP$	Pronoun
$S \rightarrow X1 VP$	[0,1]
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
$NP \rightarrow TWA \ / Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book / flight / meal / money	т
Nominal → Nominal Noun	Lexicon
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that \mid this \mid a$
$VP \rightarrow book \ / \ include \ / \ prefer$	$Noun \rightarrow book \mid flight \mid me$
$VP \rightarrow Verb NP$	$Pronoun \rightarrow I \mid she \mid me$
$VP \rightarrow X2 PP$	$Proper-Noun \rightarrow Houston \mid$
$X2 \rightarrow Verb NP$	$Aux \rightarrow does$
$VP \rightarrow Verb PP$	$Preposition \rightarrow from \mid to \mid$
$VP \rightarrow VP PP$	$Verb \rightarrow book \mid include \mid pr$
$PP \rightarrow Preposition \Lambda$	
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$\mathscr{L}_1$ Grammar	NP,	S		S		
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]	[0,4]		
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		
$S \rightarrow book \ / \ include \ / \ prefer$				, , , , , , , , , , , , , , , , , , ,		
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]		
$S \rightarrow X2 PP$			Det	NP		
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]		
$NP \rightarrow I / she / me$				Noun, Nom		
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]		
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon					
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	Noun $\rightarrow$ book   flight   meal	moneu				
$VP \rightarrow book \   \ include \   \ prefer$	$Pronoun \rightarrow I \mid she \mid me$					
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid o$	n   near   througi	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pre$					
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition \Lambda$						
	prefer a	flight	on	TWA		
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$\mathscr{L}_1$ Grammar
$S \rightarrow NP VP$
$S \rightarrow X1 VP$
$X1 \rightarrow Aux NP$
$S \rightarrow book \mid include \mid prefer$
$S \rightarrow Verb NP$
$S \rightarrow X2 PP$
$S \rightarrow Verb PP$
$S \rightarrow VP PP$
$NP \rightarrow I / she / me$
$NP \rightarrow TWA / Houston$
$NP \rightarrow Det Nominal$
$Nominal \rightarrow book \ / flight \ / meal \ / money$
$Nominal \rightarrow Nominal Noun$
$Nominal \rightarrow Nominal PP$
$VP \rightarrow book \ / \ include \ / \ prefer$
$VP \rightarrow Verb NP$
$VP \rightarrow X2 PP$
$\begin{array}{cccc} & & & & \\ & & & \\ X2 \rightarrow & Verb & NP \end{array}$
$VP \rightarrow Verb PP$
$VP \rightarrow VP PP$
$PP \rightarrow Preposition NP$

# **NP, Pronoun** [0,1]

### Lexicon

 $\begin{array}{l} Det \rightarrow that \mid this \mid a \\ Noun \rightarrow book \mid flight \mid m \\ Pronoun \rightarrow I \mid she \mid me \\ Proper-Noun \rightarrow Houston \\ Aux \rightarrow does \\ \hline Preposition \rightarrow from \mid to \mid \\ Verb \rightarrow book \mid include \mid p \end{array}$ 

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	S		S						
	[0,2]	[0,3]	[0,4]						
	Verb, VP, S		VP, X2, S						
	[1,2]	[1,3]	[1,4]						
		Det	NP						
		[2,3]	[2,4]						
			Noun, Nom						
			[3,4]						
				Prep					
real	$\mid money$			[4,5]					
$\imath \mid \dot{z}$	TWA								
<mark>on</mark>   near   through prefer									
	flight on TWA								

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## $\mathscr{L}_1$ Grammar $S \rightarrow NP VP$ $S \rightarrow X1 VP$ $X1 \rightarrow Aux NP$ $S \rightarrow book \ | \ include \ | \ prefer$ $S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I / she / me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ -----Nominal $\rightarrow$ book | flight | meal | money Nominal → Nominal Noun $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \ | \ include \ | \ prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$ -

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## NP, Pronoun [0,1]

#### Lexicon

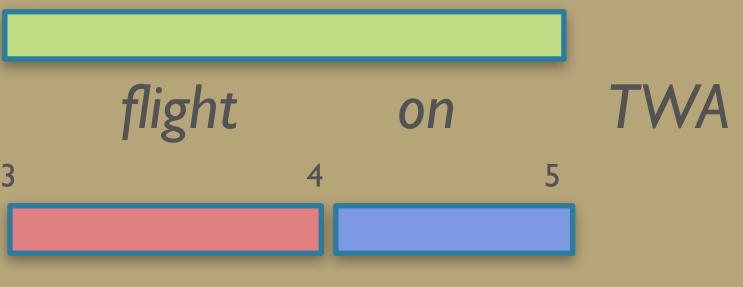
 $\begin{array}{l} Det \rightarrow that \mid this \mid a \\ Noun \rightarrow book \mid flight \mid meal \mid mea \\ Pronoun \rightarrow I \mid she \mid me \\ Proper-Noun \rightarrow Houston \mid TWA \\ Aux \rightarrow does \\ Preposition \rightarrow from \mid to \mid on \mid n \\ Verb \rightarrow book \mid include \mid prefer \end{array}$ 

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	S		S		
	[0,2]	[0,3]	[0,4]		
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]		
		Det	NP		
		[2,3]	[2,4]		
			Noun, Nom		
			[3,4]	[3,5]	
				Prep	
neal	money			[4,5]	
$n \mid 2$	TWA				
·					
01	$n \mid near \mid through$	h			





## $\mathscr{L}_1$ Grammar $S \rightarrow NP VP$ $S \rightarrow X1 VP$ $X1 \rightarrow Aux NP$ $S \rightarrow book \ | \ include \ | \ prefer$ $S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I / she / me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ -----Nominal $\rightarrow$ book | flight | meal | money Nominal → Nominal Noun $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \ | \ include \ | \ prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$

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## NP, Pronoun [0,1]

#### Lexicon

 $Det \rightarrow that | this | a$   $Noun \rightarrow book | flight | m$   $Pronoun \rightarrow I | she | me$   $Proper-Noun \rightarrow Houston$   $Aux \rightarrow does$   $Preposition \rightarrow from | to |$   $Verb \rightarrow book | include | p$ 



а

	S		S		
	[0,2]	[0,3]	[0,4]		
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]		
		Det	NP		
		[2,3]	[2,4]	[2,5]	
			Noun, Nom		
			[3,4]	[3,5]	
				Prep	
neal	money			[4,5]	
$n \mid TWA$					
or prej	n   near   through fer	l			
	flight	on	TWA		

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# $\mathscr{L}_1$ Grammar $S \rightarrow NP VP$ $S \rightarrow X1 VP$ $X1 \rightarrow Aux NP$ $S \rightarrow book \ | \ include \ | \ prefer$ $S \rightarrow Verb NP$ $S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I / she / me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ Nominal $\rightarrow$ book | flight | meal | money Nominal → Nominal Noun Nominal $\rightarrow$ Nominal PP $VP \rightarrow book \ | \ include \ | \ prefer$ $VP \rightarrow Verb NP$ $VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$ $VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$

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## NP, Pronoun [0,1]

#### Lexicon

 $Det \rightarrow that | this | a$   $Noun \rightarrow book | flight | m$   $Pronoun \rightarrow I | she | me$   $Proper-Noun \rightarrow Houston$   $Aux \rightarrow does$   $Preposition \rightarrow from | to |$   $Verb \rightarrow book | include | p$ 



a

	S		S		
	[0,2]	[0,3]	[0,4]		
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]		
		Det	NP		
		[2,3]	[2,4]	[2,5]	
	·		Noun, Nom		
			[3,4]	[3,5]	
				Prep	
neal	money			[4,5]	
$n \mid '$	TWA				
or prej	n   near   throug <sup>f</sup> er	h			

	flight		on		TW
3		4		5	



$\mathcal{L}_{1} \text{ Grammar}$ $S \rightarrow NP \ VP$ $S \rightarrow X1 \ VP$	NP, Pronoun [0,1]	S [0,2]	[0,3]	S [0,4]		
$\begin{array}{l} X1 \rightarrow Aux \ NP \\ S \rightarrow book \ / \ include \ / \ prefer \end{array}$		Verb, VP, S		VP, X2, S		
$S \rightarrow Verb \ NP$ $S \rightarrow X2 \ PP$		[1,2]	[1,3]	[1,4]	[1,5]	
$S \rightarrow Az PP$ $S \rightarrow Verb PP$			Det	NP		
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	
$NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$				Noun, Nom		
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	
$Nominal \rightarrow book \   \ flight \   \ meal \   \ money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \   \ include \   \ prefer$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $VP \rightarrow X2 \ PP$ $X2 \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$	Lexicon $Det \rightarrow that   this   a$ $Noun \rightarrow book   flight   m$ $Pronoun \rightarrow I   she   me$ $Proper-Noun \rightarrow Houston$ $Aux \rightarrow does$ $Preposition \rightarrow from   to  $ $Verb \rightarrow book   include   p$		Prep [4,5]			
$\frac{VP \rightarrow VP \ PP}{PP \rightarrow Preposition \ NP}$						
	prefer a	flight	on	TWA	ł	
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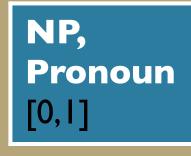
$\mathcal{L}_{1} \text{ Grammar}$ $S \rightarrow NP \ VP$ $S \rightarrow X1 \ VP$ $X1 \rightarrow Aux \ NP$	N Pr [0,	onoun	S [0,2]	[0,3]	S [0,4]		
$S \rightarrow book \ / \ include \ / \ prefer$ $S \rightarrow Verb \ NP$			Verb, VP, S [1,2]	[1,3]	VP, X2, S [1,4]	[1,5]	
$S \rightarrow X2 PP$ $S \rightarrow Verb PP$ $S \rightarrow VP PP$				<b>Det</b> [2,3]	NP [2,4]	[2,5]	
$NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$					<b>Noun, Nom</b> [3,4]	[3,5]	
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \ / \ include \ / \ prefer$	this   a   flight   mea	$l \mid money$			<b>Prep</b> [4,5]		
$VP \rightarrow Verb NP$ $VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$	$\begin{array}{c} Pronoun \rightarrow I \\ Proper-Noun \\ Aux \rightarrow does \\ Preposition \rightarrow \end{array}$	$\rightarrow$ Houston	TWA on   near   throug	h			
$VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$	$Verb \rightarrow book$						
0	prefer 2	а з	flight	<b>0</b> 4	5 5	6	



$\mathscr{L}_1$ Grammar	NP,	S		S		
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]	[0,4]		
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		
$S \rightarrow book \   \ include \   \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	
$S \rightarrow X2 PP$			Det	NP		
$S \rightarrow Verb PP$			Det			
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	
$NP \rightarrow I / she / me$				Noun, Nom		
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	
Nominal $\rightarrow$ book   flight   meal   money Lexicon	า				Prep	
$Nominal \rightarrow Nominal Noun$	$that \mid this \mid a$				ггер	
$Nominal \rightarrow Nominal PP$	$book \mid flight \mid me$	al moneu			[4,5]	
$VP \rightarrow hook   include   nreter$	$n \rightarrow I \mid she \mid me$	αι   ποπεγ				
$VP \rightarrow Verb NP$	Noun $\rightarrow$ Houston					
$VP \rightarrow X2 PP$ $Aux \rightarrow$						
$X^{0} \rightarrow Vorb ND$	tion $\rightarrow$ from   to	on   near   throug	h			
$VP \rightarrow Verh PP$	$book \mid include \mid pr$		16			
$VP \rightarrow VP PP$		rejer				
$PP \rightarrow Preposition NP$						
l prefer	а	flight	on	TWA	ł	
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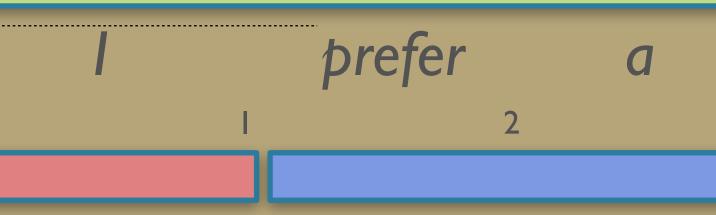


$\mathscr{L}_1$ Grammar	
$S \rightarrow NP VP$	
$S \rightarrow X1 \ VP$	
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
$NP \rightarrow TWA \mid Houston$	
$NP \rightarrow Det Nominal$	
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$	Lexico
Nominal → Nominal Noun	$Det \rightarrow$
$Nominal \rightarrow Nominal PP$	Noun
$VP \rightarrow book \   \ include \   \ prefer$	Prono
$VP \rightarrow Verb NP$	Proper
$VP \rightarrow X2 PP$	$Aux \rightarrow$
$X2 \rightarrow Verb NP$	Prepos
$VP \rightarrow Verb PP$	Verb -
$VP \rightarrow VP PP$	VCIU
$PP \rightarrow Preposition NP$	_
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## con

er-Noun  $\rightarrow$  Houston  $\rightarrow$  does  $osition \rightarrow from \mid to \mid$  $\rightarrow$  book | include |



	S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]	[1,5]	
		Det	NP		
		[2,3]	[2,4]	[2,5]	
			Noun, Nom		
			[3,4]	[3,5]	
				Prep	
real	money			[4,5]	
n   '.	TWA				
		b			
01	n   near   throug fer				
	flight	on	TWA		
3		4	5	6	



$\mathscr{L}_{1} \operatorname{Grammar}$ $S \rightarrow NP \ VP$ $S \rightarrow V1 \ VD$	NP, Pronoun
$S \rightarrow X1 \ VP$ $X1 \rightarrow Aux \ NP$ $S \rightarrow book \   \ include \   \ prefer$ $S \rightarrow Verb \ NP$ $S \rightarrow Verb \ PP$ $S \rightarrow Verb \ PP$ $S \rightarrow VP \ PP$ $NP \rightarrow I \   \ she \   \ me$ $NP \rightarrow TWA \   \ Houston$ $NP \rightarrow Det \ Nominal$	[0,1]
$Nominal \rightarrow book \   \ flight \   \ meal \   \ money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$ $VP \rightarrow book \   \ include \   \ prefer$ $VP \rightarrow Verb \ NP$ $VP \rightarrow Verb \ NP$ $X2 \rightarrow Verb \ NP$ $VP \rightarrow Verb \ PP$ $VP \rightarrow Verb \ PP$ $VP \rightarrow VP \ PP$	
$PP \rightarrow Preposition NF$	
	prefer a
0 1	2 3

	S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]	[1,5]	
		Det	NP		
		[2,3]	[2,4]	[2,5]	
			Noun, Nom		
			[3,4]	[3,5]	
				Prep	
real	$\mid money$			[4,5]	
$n \mid 2$	TWA				
or prej	n   near   throug <sup>f</sup> er	h			
	flight	on	TWA		
3		4	5	6	



$\mathcal{L}_{1} \text{ Grammar}$ $S \rightarrow NP \ VP$ $S \rightarrow X1 \ VP$ $X1 \rightarrow Aux \ NP$	<b>NP,</b> <b>Pronoun</b> [0,1]	S [0,2]	[0,3]	S [0,4]	[0,5]	
$S \rightarrow book \ / \ include \ / \ prefer$ $S \rightarrow Verb \ NP$ $S \rightarrow X2 \ PP$		Verb, VP, S [1,2]	[l,3] Det	VP, X2, S [1,4] NP	[1,5]	
$S \rightarrow Verb PP$ $S \rightarrow VP PP$ $NP \rightarrow I / she / me$			[2,3]	[2,4] Noun, Nom	[2,5]	
$NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$ $Nominal \rightarrow book \mid flight \mid meal \mid money$	Lexicon			[3,4]	[3,5] Prep	
$Nominal \rightarrow Nominal Noun$ $Nominal \rightarrow Nominal PP$ $VP \rightarrow book \ / \ include \ / \ prefer$	$Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid meal$ $Pronoun \rightarrow I \mid she \mid me$	money			[4,5]	
$VP \rightarrow Verb NP$ $VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$ $UD \rightarrow U + DD$	$\begin{array}{cccc} Proper-Noun \rightarrow Houston &   \\ Aux \rightarrow does \\ Preposition \rightarrow from &   to &   o \\ \end{array}$		h			
$VP \rightarrow Verb PP$ $VP \rightarrow VP PP$ $PP \rightarrow Preposition NP$	$Verb \rightarrow book \mid include \mid pre$					
0 1	brefer a 2 3	flight	<b>0</b> 4	5 5	6	

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$\mathscr{L}_1$ Grammar	NP,	S		S	
$S \rightarrow NP VP$	Pronoun				
$S \rightarrow X1 \ VP$	[0,1]	[0,2]	[0,3]	[0,4]	[0,5]
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S	
$S \rightarrow book \ / \ include \ / \ prefer$					
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]
$S \rightarrow X2 PP$			Det	NP	
$S \rightarrow Verb PP$					
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]
$NP \rightarrow I / she / me$				Noun, Nom	
$NP \rightarrow TWA \mid Houston$					
$NP \rightarrow Det Nominal$				[3,4]	[3,5]
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon				Prep
Nominal → Nominal Noun	$Det \rightarrow that \mid this \mid a$				Гер
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid mee$	al moneu			[4,5]
$VP \rightarrow book \   \ include \   \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	ιι   πιοπεί			
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid$	TWA			
$VP \rightarrow X2 PP$	$Aux \rightarrow does$				
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid$	on   near   throug	h		
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pr$		10		
$VP \rightarrow VP PP$					
$PP \rightarrow Preposition NP$					
1 1	orefer a	flight	on	TWA	4
0	2 3	. 0	4	5	6
	2 J				



$\mathscr{L}_1$ Grammar	
$S \rightarrow NP VP$	
$S \rightarrow X1 VP$	
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	•
$NP \rightarrow TWA / Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book / flight / meal / money	· 
Nominal → Nominal Noun	Lexico
$Nominal \rightarrow Nominal PP$	$Det \rightarrow t$
$VP \rightarrow book \ / \ include \ / \ prefer$	$- Noun \dashv$
$VP \rightarrow Verb NP$	Pronour
$VP \rightarrow X2 PP$	Proper
$X2 \rightarrow Verb NP$	$Aux \rightarrow$
$VP \rightarrow Verb PP$	Preposit
$VP \rightarrow VP PP$	$Verb \rightarrow$
$PP \rightarrow Preposition NP$	
	þrefer
	projer

### NP, Pronoun [0,1]

#### Lexicon

 $Det \rightarrow that \mid this \mid a$ Noun  $\rightarrow$  book | flight | m  $Pronoun \rightarrow I \mid she \mid me$  $Proper-Noun \rightarrow Houston$  $Aux \rightarrow does$  $Preposition \rightarrow from \mid to \mid$  $Verb \rightarrow book \mid include \mid$ 

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а

	S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]	[1,5]	
		Det	NP		
		[2,3]	[2,4]	[2,5]	
			Noun, Nom		
			[3,4]	[3,5]	
				Prep	
neal	money			[4,5]	
$n \mid r$	TWA				NNP, NP
					[5,6]
$\mid o_{i}$	$n \mid near \mid throug \ fer$	h			
2 0					
	flight	on	TWA		

5

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#### NP, Pronoun [0,1]

#### Lexicon

 $\begin{array}{l} Det \rightarrow that \mid this \mid a \\ Noun \rightarrow book \mid flight \mid meal \mid money \\ Pronoun \rightarrow I \mid she \mid me \\ Proper-Noun \rightarrow Houston \mid TWA \\ Aux \rightarrow does \\ Preposition \rightarrow from \mid to \mid on \mid near \mid through \\ Verb \rightarrow book \mid include \mid prefer \end{array}$ 

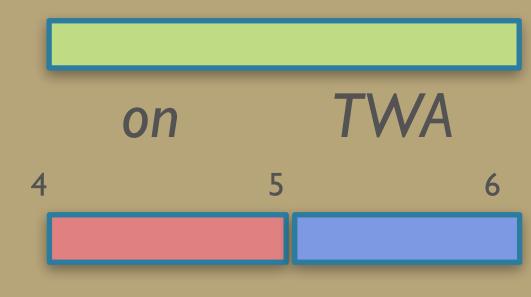
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prefer

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2

	S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]	[1,5]	
		Det	NP		
		[2,3]	[2,4]	[2,5]	
			Noun, Nom		
			[3,4]	[3,5]	
				Prep	PP
real	money			[4,5]	[4,6]
2 /	TWA				NNP, NP
,					[5,6]
01	$n \mid near \mid through$	h			





$\mathscr{L}_1$ Grammar	
$S \rightarrow NP VP$	
$S \rightarrow X1 \ VP$	
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I \mid she \mid me$	
$NP \rightarrow TWA / Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book / flight / meal / money	T •
Nominal → Nominal Noun	
Nominal   Nominal   PP	$Det \rightarrow$
$VP \rightarrow book \   \ include \   \ prefer$	$\cdot Noun - D$
$VP \rightarrow Verb NP$	Pronout
$VP \rightarrow X2 PP$	Proper-
$X2 \rightarrow Verb NP$	$Aux \rightarrow$
$VP \rightarrow Verb PP$	Preposit
$VP \rightarrow VP PP$	$Verb \rightarrow$
$PP \rightarrow Preposition NP$	
	prefer
	projer

## **NP, Pronoun** [0,1]

#### Lexicon

 $Det \rightarrow that \mid this \mid a$ Noun  $\rightarrow$  book | flight | m  $Pronoun \rightarrow I \mid she \mid me$  $Proper-Noun \rightarrow Houston$  $Aux \rightarrow does$  $Preposition \rightarrow from \mid to \mid$  $Verb \rightarrow book \mid include \mid$ 

2

	S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]	[1,5]	
		Det	NP		
		[2,3]	[2,4]	[2,5]	
			Noun, Nom		Nom
			[3,4]	[3,5]	[3,6]
				Prep	PP
neal	money			[4,5]	[4,6]
$m \mid '$	ТWA				NNP, NP
10   -					[5,6]
or prej	$n \mid near \mid throug fer$	h			
	flight	on	TWA		
3		4	5	6	



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#### NP, Pronoun [0,1]

#### Lexicon

 $Det \rightarrow that | this | a$   $Noun \rightarrow book | flight | m$   $Pronoun \rightarrow I | she | me$   $Proper-Noun \rightarrow Houston$   $Aux \rightarrow does$   $Preposition \rightarrow from | to |$   $Verb \rightarrow book | include | p$ 

2

prefer

	S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]	[1,5]	
		Det	NP		
		[2,3]	[2,4]	[2,5]	
			Noun, Nom		Nom
			[3,4]	[3,5]	[3,6]
				Prep	PP
real	money			[4,5]	[4,6]
$n \mid '$	TWA				NNP, NP
					[5,6]
or pref	n   near   throug fer	h			
	flight	on	TWA		
3		4	5	6	



$\mathscr{L}_1$ Grammar	
$S \rightarrow NP VP$	
$S \rightarrow X1 VP$	
$X1 \rightarrow Aux NP$	
$S \rightarrow book \   \ include \   \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I / she / me$	
$NP \rightarrow TWA / Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book   flight   meal   money	
Nominal   Nominal Noun	
$Nominal \rightarrow Nominal PP$	De
$VP \rightarrow book \   \ include \   \ prefer$	No
$VP \rightarrow Verb NP$	Pro
$VP \rightarrow X2 PP$	Pro
$X2 \rightarrow Verb NP$	Au Dm
$VP \rightarrow Verb PP$	Pro
$VP \rightarrow VP PP$	Ve
$PP \rightarrow Preposition NP$	
	pret
	pre
0	

# NP, Pronoun [0,1]

#### xicon

 $et \rightarrow that \mid this \mid a$ oun \rightarrow book \mid flight \mid me conoun \rightarrow I \mid she \mid me  $oper-Noun \rightarrow Houston$  $x \rightarrow does$  $eposition \rightarrow from \mid to \mid$  $rb \rightarrow book \mid include \mid$ 

2



	S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]	[1,5]	
		Det	NP		NP
		[2,3]	[2,4]	[2,5]	[2,6]
			Noun, Nom		Nom
			[3,4]	[3,5]	[3,6]
				Prep	PP
neal	money			[4,5]	[4,6]
$n \mid '$	TWA				NNP, NP
.   .					[5,6]
or prej	n   near   throug fer	h			
1 J					
	flight	on	TWA		
3	10	4	5	6	
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#### NP, Pronoun [0,1]

#### Lexicon

 $Det \rightarrow that | this | a$   $Noun \rightarrow book | flight | m$   $Pronoun \rightarrow I | she | me$   $Proper-Noun \rightarrow Houston$   $Aux \rightarrow does$   $Preposition \rightarrow from | to |$   $Verb \rightarrow book | include | p$ 



	S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]	[1,5]	
		Det	NP		NP
		[2,3]	[2,4]	[2,5]	[2,6]
			Noun, Nom		Nom
			[3,4]	[3,5]	[3,6]
				Prep	PP
neal	$\mid money$			[4,5]	[4,6]
$m \mid '$	ТWA				NNP, NP
10   -					[5,6]
or pref	$n \mid near \mid throug$ fer	h			
proj					
	flight	on	TWA		
3	10	4	5	6	
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#### NP, Pronoun [0,1]

#### Lexicon

 $Det \rightarrow that | this | a$   $Noun \rightarrow book | flight | m$   $Pronoun \rightarrow I | she | me$   $Proper-Noun \rightarrow Houston$   $Aux \rightarrow does$   $Preposition \rightarrow from | to |$   $Verb \rightarrow book | include | p$ 



	S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	
	Verb, VP, S		VP, X2, S		
	[1,2]	[1,3]	[1,4]	[1,5]	
		Det	NP		NP
		[2,3]	[2,4]	[2,5]	[2,6]
			Noun, Nom		Nom
			[3,4]	[3,5]	[3,6]
				Prep	PP
neal	$\mid money$			[4,5]	[4,6]
$m \mid '$	TWA				NNP, NP
10   .					[5,6]
or prej	n   near   throug fer	h			
	flight	on	TWA		
3		4	5	6	
				W UN	VIVERSITY of WASHINGT



$\mathscr{L}_1$ Grammar		NP,	S		S		
$S \rightarrow NP VP$		Pronoun			/-		
$S \rightarrow X1 VP$		[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$			Verb, VP, S		<b>VP, X2, S</b>		
$S \rightarrow book \mid include \mid prefer$							
$S \rightarrow Verb NP$			[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$				Det	NP		NP
$S \rightarrow Verb PP$							
$S \rightarrow VP PP$				[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$					Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$							
$NP \rightarrow Det Nominal$					[3,4]	[3,5]	[3,6]
Nominal $\rightarrow$ book   flight   meal   money	Lexicon						PP
Nominal → Nominal Noun	$Det \rightarrow tha$	+   thic   a				Prep	
$Nominal \rightarrow Nominal PP$		$ook \mid flight \mid mea$	1 monou			[4,5]	[4,6]
$VP \rightarrow book \   \ include \   \ prefer$			u   money			[ ',9]	
$VP \rightarrow Verb NP$		$\bullet I \mid she \mid me$					NNP, NP
$VP \rightarrow X2 PP$	÷	$un \rightarrow Houston \mid$	IVVA				FE (1
$X2 \rightarrow Verb NP$	$Aux \rightarrow doo$			1			[5,6]
$VP \rightarrow Verb PP$			$pn \mid near \mid through$				
$VP \rightarrow VP PP$	vero → oo	$ok \mid include \mid pre$	ejer				
$PP \rightarrow Preposition NP$							
	prefer	а	flight	on	TWA		
0	2	3		4	5	6	



$\mathscr{L}_1$ Grammar	NP,	S		S		
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 \ VP$	[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		VP
$S \rightarrow book \   \ include \   \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$			Det	NP		NP
$S \rightarrow Verb PP$						_
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$				Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon				Prep	PP
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	Noun $\rightarrow$ book   flight   meal	money			[4,5]	[4,6]
$VP \rightarrow book \mid include \mid prefer$	$Pronoun \rightarrow I \mid she \mid me$					NNP, NP
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 1$	TWA				,
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					[5,6]
$X2 \rightarrow Verb NP$	Preposition $\rightarrow$ from   to   or	$n \mid near \mid through$	$\imath$			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid prej$					
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$						
1 1	orefer a	flight	on	TWA		
0	2 3		4	5	6	
					W U	NIVERSITY of WASHINGTC



$\mathscr{L}_1$ Grammar		NP,	S		S		
$S \rightarrow NP VP$		Pronoun					
$S \rightarrow X1 VP$		[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$			Verb, VP, S		VP, X2, S		VP, X2
$S \rightarrow book \   \ include \   \ prefer$					,, .		
$S \rightarrow Verb NP$			[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$				Det	NP		NP
$S \rightarrow Verb PP$				Det			
$S \rightarrow VP PP$	_			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$					Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$							
$NP \rightarrow Det Nominal$					[3,4]	[3,5]	[3,6]
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon					Prep	PP
Nominal → Nominal Noun	$Det \rightarrow that$	t this a				rrep	
$Nominal \rightarrow Nominal PP$		$pok \mid flight \mid meal$	1 monou			[4,5]	[4,6]
$VP \rightarrow book \   \ include \   \ prefer$		$I \mid she \mid me$	, money			[ ",• ]	
$VP \rightarrow Verb NP$		$n \rightarrow Houston \mid$					NNP, NP
$VP \rightarrow X2 PP$	$Aux \rightarrow doe$	1					[5 4]
$X2 \rightarrow Verb NP$			m   m a m   th may a	L			[5,6]
$VP \rightarrow Verb PP$			$n \mid near \mid through$				
$VP \rightarrow VP PP$	Vero - 000	$pk \mid include \mid pre$	jer.			_	
$PP \rightarrow Preposition NP$							
	prefer	а	flight	on	TWA		
0	2	3		4	5	6	



$\mathscr{L}_1$ Grammar		NP,	S		S		
$S \rightarrow NP VP$		Pronoun	<b>10 01</b>		FO 41	ΓΟ ΓΙ	
$S \rightarrow X1 \ VP$ $X1 \rightarrow Aux \ NP$		[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$S \rightarrow book \   \ include \   \ prefer$			Verb, VP, S		<b>VP, X2, S</b>		VP, X2, S
			[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow Verb NP$ $S \rightarrow X2 PP$			L·,—J	Det	NP	[.,.]	NP
$S \rightarrow Verb PP$				Det			
$S \rightarrow VP PP$				[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$					Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$							
					[3,4]	[3,5]	[3,6]
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$ $Nominal \rightarrow Nominal \ Noun$	Lexicon					Prep	PP
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that$					- /	F 4 43
$VP \rightarrow book \ / \ include \ / \ prefer$		$pok \mid flight \mid mea$	$l \mid money$			[4,5]	[4,6]
$VP \rightarrow Verb NP$		$I \mid she \mid me$					NNP, NP
$VP \rightarrow X2 PP$	$Aux \rightarrow doe.$	$n \rightarrow Houston \mid$	TWA				rs 41
$X2 \rightarrow Verb NP$			$n \mid near \mid through$	h			[5,6]
$VP \rightarrow Verb PP$		$bk \mid include \mid pre$		U			
$VP \rightarrow VP PP$			JCI			_	
$PP \rightarrow Preposition NP$							
	prefer	а	flight	on	TWA		
0	2	3		4	5	6	



$\mathscr{L}_1$ Grammar		NP,	S		S		
$S \rightarrow NP VP$		Pronoun	50.07	50.07	50 (7		
$S \rightarrow X1 \ VP$		[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$			Verb, VP, S		<b>VP, X2, S</b>		<b>VP, X2, S</b>
$S \rightarrow book \   \ include \   \ prefer$							
$S \rightarrow Verb NP$			[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$				Det	NP		NP
$S \rightarrow Verb PP$							
$S \rightarrow VP PP$				[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$					Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$							
$NP \rightarrow Det Nominal$					[3,4]	[3,5]	[3,6]
Nominal $\rightarrow$ book   flight   meal   money	Lexicon						PP
$Nominal \rightarrow Nominal Noun$		+ + this + a				Prep	
$Nominal \rightarrow Nominal PP$	$Det \rightarrow tha$ $New \rightarrow b$		1   monou			[4,5]	[4,6]
$VP \rightarrow book \   \ include \   \ prefer$		$ook \mid flight \mid mea$	i   money			[ ',9]	
$VP \rightarrow Verb NP$		$\bullet I \mid she \mid me$					NNP, NP
$VP \rightarrow X2 PP$	<b>^</b>	$un \rightarrow Houston \mid$	IVVA				FE (1
$X2 \rightarrow Verb NP$	$Aux \rightarrow doe$			1			[5,6]
$VP \rightarrow Verb PP$		$n \rightarrow from \mid to \mid o$		l			
$VP \rightarrow VP PP$	Verb → bo	$ok \mid include \mid pre$	fer				
$PP \rightarrow Preposition NP$							
	prefer	а	flight	on	TWA		
0	2	3		4	5	6	



$\mathscr{L}_1 \operatorname{\mathbf{Grammar}}_{S \to NP \ VP}$		NP,	S		S		
$S \rightarrow NP \ VP$ $S \rightarrow X1 \ VP$		Pronoun [0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$			Verb, VP, S		VP, X2, S		VP, X2, S
$S \rightarrow book \mid include \mid prefer$ $S \rightarrow Verb NP$			FL 01	LI 21	FI 47	F 1 F 1	FL / 1
$S \rightarrow X2 PP$			[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow Verb PP$				Det	NP		NP
$S \rightarrow VP PP$				[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$					Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$							
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$					[3,4]	[3,5]	[3,6]
$Nominal \rightarrow Nominal Noun$	Lexicon					Prep	PP
$Nominal \rightarrow Nominal PP$		$at \mid this \mid a$				[4,5]	[4,6]
$VP \rightarrow book \ / \ include \ / \ prefer$		$ook \mid flight \mid meal$ + $I \mid she \mid me$	money			[4,5]	
$VP \rightarrow Verb NP$		$un \rightarrow Houston \mid 1$	TWA				NNP, NP
$VP \rightarrow X2 PP$	$Aux \rightarrow doe$						[5,6]
$\begin{array}{cccc} X2 \rightarrow & Verb & NP \\ VP \rightarrow & Verb & PP \end{array}$	Preposition	$n \rightarrow from \mid to \mid ot$	n   near   through	h			
$VP \rightarrow VP PP$	$Verb \rightarrow bo$	$ook \mid include \mid prej$	fer				
$PP \rightarrow Preposition NP$							
	prefer	а	flight	on	TWA		
0 I	2	3		4	5	6	



$\mathscr{L}_{1} \operatorname{Grammar}$ $S \rightarrow NP \ VP$	NP, Pronoun	S	FO 01	S	F0 F1	
$S \rightarrow X1 \ VP$ $X1 \rightarrow Aux \ NP$	[0,1]	[0,2] Verb, VP, S	[0,3]	[0,4] VP, X2, S	[0,5]	VP, X2, S
$S \rightarrow book \   \ include \   \ prefer$ $S \rightarrow Verb \ NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$ $S \rightarrow Verb PP$			Det	NP		NP
$S \rightarrow VP PP$ $NP \rightarrow I \ / \ she \ / \ me$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$				Noun, Nom	<b>Г</b> Э <b>Г</b> І	Nom
$Nominal \rightarrow book \ / flight \ / meal \ / money$ $Nominal \rightarrow Nominal \ Noun$	$\begin{array}{c} \mathbf{Lexicon} \\ Det \rightarrow that \mid this \mid a \end{array}$			[3,4]	[3,5] Prep	[3,6] PP
$Nominal \rightarrow Nominal PP$ $VP \rightarrow book \mid include \mid prefer$ $VP \rightarrow Verb NP$	$Noun \rightarrow book \mid flight \mid meal$ $Pronoun \rightarrow I \mid she \mid me$	money			[4,5]	[4,6] NNP, NP
$VP \rightarrow X2 PP$ $X2 \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid Aux \rightarrow does$		1			[5,6]
$VP \rightarrow Verb PP$ $VP \rightarrow VP PP$	$\begin{array}{cccc} Preposition \rightarrow from \mid to \mid or \\ Verb \rightarrow book \mid include \mid preposition \\ \end{array}$		l			
$PP \rightarrow Preposition NP$						
	prefer a	flight	on	TWA		
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$\mathscr{L}_1$ Grammar	NP,	S		S		
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		VP, X2, S
$S \rightarrow book \   \ include \   \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$			Det	NP		NP
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$				Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$ $Nominal \rightarrow Nominal \ Noun$	Lexicon				Prep	PP
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that \mid this \mid a$	7			F4 51	[4 6]
$VP \rightarrow book \ / \ include \ / \ prefer$	Noun $\rightarrow$ book   flight   mea	l   money			[4,5]	[4,6]
$VP \rightarrow Verb NP$	$Pronoun \rightarrow I \mid she \mid me$	πτλ				NNP, NP
$VP \rightarrow X2 PP$	$Proper-Noun \rightarrow Houston \mid$	IVVA				FE (1
$X2 \rightarrow Verb NP$	$Aux \rightarrow does$	a la can l thacas	L			[5,6]
$VP \rightarrow Verb PP$	$Preposition \rightarrow from \mid to \mid o$ $Vorb \rightarrow book \mid in olar do \mid max$					
$VP \rightarrow VP PP$	$Verb \rightarrow book \mid include \mid pre$	ejer			_	
$PP \rightarrow Preposition NP$						
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$\mathscr{L}_1$ Grammar	NP,	S		S		
$S \rightarrow NP \ VP$ $S \rightarrow X1 \ VP$	<b>Pronoun</b> [0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		VP, X2, S
$S \rightarrow book \ / \ include \ / \ prefer$				, , , , , , , , , , , , , , , , , , , ,		<b>VI</b> , <b>A</b> 2, <b>S</b>
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$			Det	NP		NP
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I \mid she \mid me$ $NP \rightarrow TWA \mid Houston$				Noun, Nom		Nom
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$ $Nominal \rightarrow Nominal \ Noun$ $Nominal \rightarrow Nominal \ PP$	$\begin{array}{c} \mathbf{Lexicon} \\ Det \rightarrow that \mid this \mid a \end{array}$				Prep	PP
$VP \rightarrow book \ / \ include \ / \ prefer$	Noun $\rightarrow$ book   flight   mea	$l \mid money$			[4,5]	[4,6]
$VP \rightarrow Verb NP$	$Pronoun \rightarrow I \mid she \mid me$					NNP, NP
$VP \rightarrow X2 PP$	$Proper-Noun \rightarrow Houston \mid \\Aux \rightarrow does$	TWA				FE 61
$X2 \rightarrow Verb NP$	$Aux \rightarrow aoes$ $Preposition \rightarrow from \mid to \mid o$	n   near   through	h			[5,6]
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pre$		U			
$VP \rightarrow VP PP$		<i>J U I</i>				
$PP \rightarrow Preposition NP$						
	prefer a	flight	on	TWA		
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$\mathscr{L}_1$ Grammar	NP,	S		S		
$S \rightarrow NP VP$	Pronou	n				
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		VP, X2, S
$S \rightarrow book \ / \ include \ / \ prefer$				, , , , , , , , , , , , , , , , , , , ,		
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$			Det	NP		NP
$S \rightarrow Verb PP$			Det			
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$						
$NP \rightarrow TWA \ / Houston$				Noun, Nom		Nom
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon				Prep	PP
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	Noun $\rightarrow$ book   flight	meal   money			[4,5]	[4,6]
$VP \rightarrow book \mid include \mid prefer$	$Pronoun \rightarrow I \mid she \mid m$					NNP, NP
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Housto$					
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					[5,6]
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid te$	o   on   near   throua	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid$					
$VP \rightarrow VP PP$		I. J.				
$PP \rightarrow Preposition NP$						
	prefer a	flight	on	TWA		
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$\mathscr{L}_1$ Grammar	NP,	S		S		
$S \rightarrow NP VP$	Pronoun	FO 01	50 21	FO 41		
$S \rightarrow X1 \ VP$	[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$		Verb, VP, S		VP, X2, S		<b>VP, X2, S</b>
$S \rightarrow book \ / \ include \ / \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$			Det	NP		NP
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$				Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon				Prep	PP
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid meal$	ี moneu			[4,5]	[4,6]
$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	Thomas y				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid :$	$T W \Lambda$				NNP, NP
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					[5 6]
$X2 \rightarrow Verb NP$		n   noan   through	h			[5,6]
$VP \rightarrow Verb PP$	$Preposition \rightarrow from \mid to \mid or$ $Vorb \rightarrow book \mid in alu do \mid model$					
$VP \rightarrow VP PP$	$Verb \rightarrow book \mid include \mid pres$	191			_	
$PP \rightarrow Preposition NP$						
	orefer a	flight	on	TWA		
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$\mathscr{L}_1$ Grammar	NP,	S		S		
$S \rightarrow NP VP$	Pronoun					
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	
$X1 \rightarrow Aux NP$		Verb, VP, S		<b>VP, X2, S</b>		VP, X2, S
$S \rightarrow book \   \ include \   \ prefer$						
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$			Det	NP		NP
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$				Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
$Nominal \rightarrow book \ / flight \ / meal \ / money$	Lexicon				Prep	PP
Nominal → Nominal Noun	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	$Noun \rightarrow book \mid flight \mid mea$	l   moneu			[4,5]	[4,6]
$VP \rightarrow book \   \ include \   \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	, , , , , , , , , , , , , , , , , , ,				NNP, NP
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					[5,6]
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid o$	$n \mid near \mid through$	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pre$					
$VP \rightarrow VP PP$		<i>J C i</i>				
$PP \rightarrow Preposition NP$						
	prefer a	flight	on	TWA		
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$\mathscr{L}_1$ Grammar	NP,	S		S		
$S \rightarrow NP \ VP$ $S \rightarrow X1 \ VP$	<b>Pronoun</b> [0,1]	[0,2]	[0,3]	[0,4]	[0,5]	[0,6]
$\begin{array}{c} X1 \rightarrow Aux \ NP \end{array}$			[0,5]		[0,0]	
$S \rightarrow book \ / \ include \ / \ prefer$		Verb, VP, S		<b>VP, X2, S</b>		VP, X2, S
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$			Det	NP		NP
$S \rightarrow Verb PP$						
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$				Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$ $NP \rightarrow Det Nominal$				50 47	50 53	50 47
$Nominal \rightarrow book \ / \ flight \ / \ meal \ / \ money$				[3,4]	[3,5]	[3,6]
$Nominal \rightarrow Nominal Noun$	Lexicon				Prep	PP
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that \mid this \mid a$ $Noun \rightarrow book \mid flight \mid meal$				[4,5]	[4,6]
$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	money				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 2$	TWA				NNP, NP
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					[5,6]
$X2 \rightarrow Verb NP$ $VD \rightarrow Verb DD$	$Preposition \rightarrow from \mid to \mid or$	$n \mid near \mid through$	h			
$VP \rightarrow Verb PP$ $VP \rightarrow VP PP$	$Verb \rightarrow book \mid include \mid pres$	fer				
$PP \rightarrow Preposition NP$						
	prefer a	flight	on	TWA	ł	
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$\mathscr{L}_1$ Grammar	NP,
$S \rightarrow NP VP$	Pronoun
$S \rightarrow X1 VP$	[0,1]
$X1 \rightarrow Aux NP$	
$S \rightarrow book \ / \ include \ / \ prefer$	
$S \rightarrow Verb NP$	
$S \rightarrow X2 PP$	
$S \rightarrow Verb PP$	
$S \rightarrow VP PP$	
$NP \rightarrow I \mid she \mid me$	•
$NP \rightarrow TWA \mid Houston$	
$NP \rightarrow Det Nominal$	
Nominal $\rightarrow$ book   flight   meal   money	Lexicon
Nominal  → Nominal Noun	
$Nominal \rightarrow Nominal PP$	$Det \rightarrow that \mid this \mid a$
$VP \rightarrow book \ / \ include \ / \ prefer$	$ Noun \rightarrow book \mid flight \mid mea$
$VP \rightarrow Verb NP$	$Pronoun \rightarrow I \mid she \mid me$
$VP \rightarrow X2 PP$	$Proper-Noun \rightarrow Houston \mid$
$X2 \rightarrow Verb NP$	$Aux \rightarrow does$
$VP \rightarrow Verb PP$	$Preposition \rightarrow from \mid to \mid o$
$VP \rightarrow VP PP$	$Verb \rightarrow book \mid include \mid pre$
$PP \rightarrow Preposition NP$	
	prefer a
0	2 3

	S		S		S		
	[0,2]	[0,3]	[0,4]	[0,5]	[0,6]		
	Verb, VP, S		<b>VP, X2, S</b>		<b>VP, X2, S</b>		
	[1,2]	[1,3]	[1,4]	[1,5]	[1,6]		
		Det	NP		NP		
		[2,3]	[2,4]	[2,5]	[2,6]		
			Noun, Nom		Nom		
			[3,4]	[3,5]	[3,6]		
				Prep	PP		
neal	money			[4,5]	[4,6]		
$n \mid$	TWA				NNP, NP		
					[5,6]		
o pre	n   near   throug. fer	h					
I J							
flight on TWA							
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$\mathscr{L}_1$ Grammar		•				
$S \rightarrow NP VP$	NP, Pronoun	S		S		S
$S \rightarrow X1 VP$	[0,1]	[0,2]	[0,3]	[0,4]	[0,5]	[0,6]
$X1 \rightarrow Aux NP$						
$S \rightarrow book \   \ include \   \ prefer$		Verb, VP, S		<b>VP, X2, S</b>		<b>VP, X2, S</b>
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$		L / J	Det	NP	L / J	NP
$S \rightarrow Verb PP$			Det			
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$				Noun, Nom		Nom
$NP \rightarrow TWA \mid Houston$						
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
Nominal $\rightarrow$ book   flight   meal   money	Lexicon				Prep	PP
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$					
$Nominal \rightarrow Nominal PP$	Noun $\rightarrow$ book   flight   meal	money			[4,5]	[4,6]
$VP \rightarrow book \   \ include \   \ prefer$ $VP \rightarrow Verb \ NP$	$Pronoun \rightarrow I \mid she \mid me$					NNP, NP
$VP \rightarrow Vero NP$ $VP \rightarrow X2 PP$	$Proper-Noun \rightarrow Houston \mid 2$	ΓWA				
$\begin{array}{cccc} & & & & \\ & & & \\ & X2 \rightarrow & Verb \ NP \end{array}$	$Aux \rightarrow does$					[5,6]
$VP \rightarrow Verb PP$	$Preposition \rightarrow from \mid to \mid or$		h			
$VP \rightarrow VP PP$	$Verb \rightarrow book \mid include \mid pref$	fer				
$PP \rightarrow Preposition NP$						
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	prejei	Ingitt	UIT			
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$\mathscr{L}_1 \operatorname{Grammar}_{S \to NP \ VP}$	NP,	S		S		S
$S \rightarrow NP VP$ $S \rightarrow X1 VP$	Pronoun [0]]	FO 21	[0,3]	[0,4]	[0,5]	[0 6]
$\begin{array}{cccc} S & \bullet & AI & \bullet I \\ X1 & \to & Aux & NP \end{array}$	[0,1]	[0,2]	[0,3]		[0,3]	[0,6]
$S \rightarrow book \   \ include \   \ prefer$		Verb, VP, S		<b>VP, X2, S</b>		<b>VP, X2, S</b>
$S \rightarrow Verb NP$		LI 01	LI 31	FT <b>1</b> 1	[] []	<b>[] 4]</b>
$S \rightarrow X2 PP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow Verb PP$			Det	NP		NP
$S \rightarrow VP PP$			۲C C1	۲۵ <i>(</i> ۱	[2 []	[2] (1]
$NP \rightarrow I / she / me$	-		[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow TWA / Houston$				Noun, Nom		Nom
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
Nominal $\rightarrow$ book   flight   meal   money	Lovicon			[-,.]		
$Nominal \rightarrow Nominal Noun$	$\begin{array}{c} \textbf{Lexicon} \\ Det \rightarrow that \mid this \mid a \end{array}$				Prep	PP
$Nominal \rightarrow Nominal PP$	- Noun $\rightarrow$ book   flight   meal	monou			[4,5]	[4,6]
$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	money				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 2$	TWA				NNP, NP
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					[5,6]
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid or$	n   near   throuai	h			[3,0]
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pref$					
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$						
	prefer a	flight	on	TWA		
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$\mathscr{L}_1 \operatorname{Grammar}_{S \to NP \ VP}$	NP,	S		S		S
$S \rightarrow NP VP$ $S \rightarrow X1 VP$	Pronoun [0,1]	[0,2]	[0,3]	[0,4]	[0,5]	[0,6]
$\begin{array}{cccc} S & \bullet & AI & \bullet I \\ X1 & \to & Aux & NP \end{array}$					[0,5]	
$S \rightarrow book \   \ include \   \ prefer$		Verb, VP, S		<b>VP, X2, S</b>		<b>VP, X2, S</b>
$S \rightarrow Verb NP$		<b>[]</b> [] []	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$		[1,2]			[י,י]	
$S \rightarrow Verb PP$			Det	NP		NP
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$			[2,5]		[2,5]	
$NP \rightarrow TWA / Houston$				Noun, Nom		Nom
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
Nominal $\rightarrow$ book   flight   meal   money	Lexicon			[-,.]		PP
$Nominal \rightarrow Nominal Noun$	$Det \rightarrow that \mid this \mid a$				Prep	
$Nominal \rightarrow Nominal PP$	$- Noun \rightarrow book \mid flight \mid meal$	moneu			[4,5]	[4,6]
$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow I \mid she \mid me$	money				
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 2$	TWA				NNP, NP
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					[5,6]
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid or$	$n \mid near \mid through$	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid pref$					
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$						
	prefer a	flight	on	TWA		
0	2 3		4	5	6	
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$\mathscr{L}_1 \operatorname{Grammar}_{S \to NP \ VP}$	NP, Propour	S		S		S
$S \rightarrow X1 VP$	Pronoun [0,1]	[0,2]	[0,3]	[0,4]	[0,5]	[0,6]
$\begin{array}{cccc} X & & X & & Y \\ X & & X \\ X & \rightarrow & Aux & NP \end{array}$			[0,5]			
$S \rightarrow book \ / \ include \ / \ prefer$		Verb, VP, S		<b>VP, X2, S</b>		<b>VP, X2, S</b>
$S \rightarrow Verb NP$		[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
$S \rightarrow X2 PP$		[י, ב]			[י,כ]	
$S \rightarrow Verb PP$			Det	NP		NP
$S \rightarrow VP PP$			[2,3]	[2,4]	[2,5]	[2,6]
$NP \rightarrow I / she / me$			[2,5]		[2,3]	
$NP \rightarrow TWA / Houston$				Noun, Nom		Nom
$NP \rightarrow Det Nominal$				[3,4]	[3,5]	[3,6]
Nominal $\rightarrow$ book / flight / meal / money	Lexicon				Prep	PP
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$VP \rightarrow book \ / \ include \ / \ prefer$	$Pronoun \rightarrow I \mid she \mid me$					NNP, NP
$VP \rightarrow Verb NP$	$Proper-Noun \rightarrow Houston \mid 2$	TWA				
$VP \rightarrow X2 PP$	$Aux \rightarrow does$					[5,6]
$X2 \rightarrow Verb NP$	$Preposition \rightarrow from \mid to \mid or$	$n \mid near \mid through$	h			
$VP \rightarrow Verb PP$	$Verb \rightarrow book \mid include \mid prej$					
$VP \rightarrow VP PP$						
$PP \rightarrow Preposition NP$						
	prefer a	flight	on	TWA		
0	2 3		4	5	6	
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## Current CKY Algorithm

- Limitations:
- Only stores non-terminals in cell
  Not rules or cells corresponding to RHS
  Stores SETS of non-terminals
  Multiple rules with same LHS collide
  Currently only *acceptance/recognition*





• Pair each nonterminal with back-pointer to cells from which it was derived

• Last step:

• construct trees from back-pointers in [0, n]





NP, Pronoun [0,1]

S		S		
[0,2]	[0,3]	[0,4]	[0,5]	
Verb, VP, S		VP, X2, S		VP
[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
	Det	NP		NP
	[2,3]	[2,4]	[2,5]	[2,6]
		Noun, Nom		Nom
		[3,4]	[3,5]	[3,6]
			Prep	PP
			[4,5]	[4,6]
				NNP, NP
				[5,6]





bp\_1 = BackPointer()
bp\_1.l\_child = [VP, (1,4)]
bp\_1.r\_child = [PP, (4,6)]

S		S		
[0,2]	[0,3]	[0,4]	[0,5]	
Verb, VP, S		VP, X2, S		VP
[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
	Det	NP		NP
	[2,3]	[2,4]	[2,5]	[2,6]
		Noun, Nom		Nom
		[3,4]	[3,5]	[3,6]
			Prep	PP
			[4,5]	[4,6]
				NNP, NP
				[5,6]

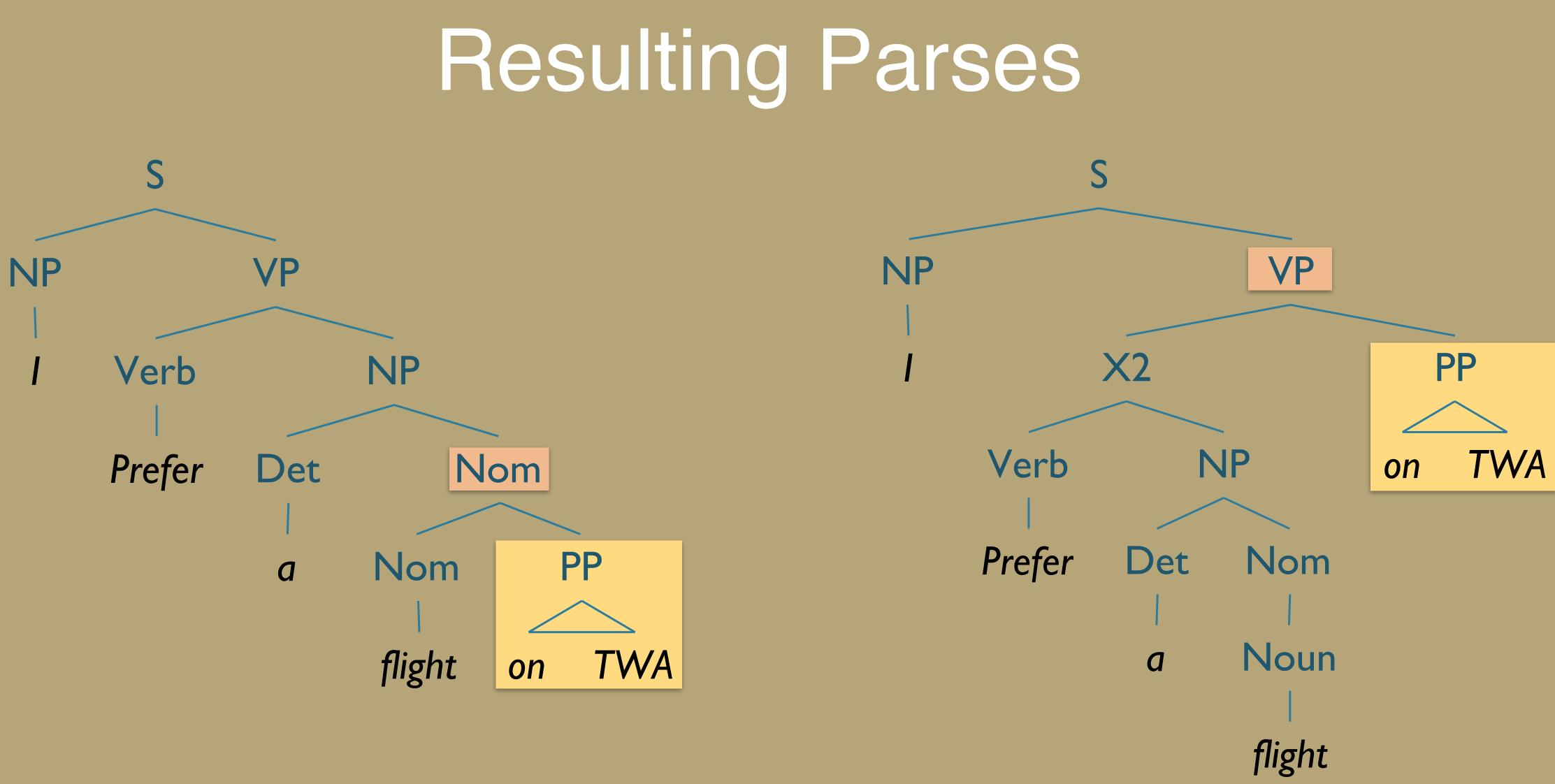




bp\_2 = BackPointer()
bp\_2.l\_child = [X2, (1,4)]
bp\_2.r\_child = [PP, (4,6)]

S		S		
[0,2]	[0,3]	[0,4]	[0,5]	
Verb, VP, S		VP, X2, S		VP
[1,2]	[1,3]	[1,4]	[1,5]	[1,6]
	Det	NP		NP
	[2,3]	[2,4]	[2,5]	[2,6]
		Noun, Nom		Nom
		[3,4]	[3,5]	[3,6]
			Prep	PP
			[4,5]	[4,6]
				NNP, NP
				[5,6]





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### CKY Discussion

- Running time:
  - $O(n^3)$  where *n* is the length of the input string
  - Inner loop grows as square of # of non-terminals
- Expressiveness:
  - As implemented, requires CNF
    - Weak equivalence to original grammar
    - Doesn't capture full original structure
    - Back-conversion?
      - Can do binarization, terminal conversion
      - Unit productions requires change in CKY

ngth of the input string are of # of non-terminals

es CNF riginal grammar

erminal conversion ires change in CKY



### Parsing: PCFGs

Deep Processing Techniques for NLP October 7, 2019

### Ling 571





### Probabilistic Context-free Grammars: Roadmap

- Motivation: Ambiguity
- Approach:
  - Definition
  - Disambiguation
  - Parsing
  - Evaluation
  - Enhancements

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## Motivation

#### • What about ambiguity?

#### • Current algorithm can *represent* it

• ...can't resolve it.

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# Probabilistic Parsing

- Provides strategy for solving disambiguation problem

  - Compute the probability of all analyses • Select the most probable

- Employed in language modeling for speech recognition
  - N-gram grammars predict words, constrain search • Also, constrain generation, translation





## **PCFGs: Formal Definition**

a set of <b>non-terr</b>	N
a set of <b>termin</b>	$\sum$
a set of rules of productions, each of the $A$ is a non-terminal, $eta$ is a string of sym	R
is a number betw	
a desig	S

#### minal symbols (or variables)

**nal symbols** (disjoint from N)

the form  $A \rightarrow \beta[p]$ , where A is a non-terminal where

ymbols from the infinite set of strings  $(\Sigma \cup N)*$  and p

veen 0 and 1 expressing P(eta|A)

gnated **start symbol** 



- will be expanded as RHS
- $P(A \rightarrow \beta)$
- $P(A \rightarrow \beta | A)$
- $P(\boldsymbol{\beta}|A)$
- $P(RHS \mid LHS)$
- really meant.

## PCFGS

# Augment each production with probability that LHS

### • NB: the first is often used; but the latter are what's

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• Sum over all possible expansions is 1

# ß

- is 1
  - Recursive rules often yield inconsistent grammars (Booth & Thompson, 1973)

# PCFGS

### $\sum P(A \to \beta) = 1$

### • A PCFG is *consistent* if sum of probabilities of all sentences in language





# Example PCFG: Augmented $\mathscr{L}_1$

#### Grammar

$S \rightarrow NP VP$	[.80]
$S \rightarrow Aux NP VP$	[.15]
$S \rightarrow VP$	[.05]
$NP \rightarrow Pronoun$	[.35]
$NP \rightarrow Proper-Noun$	[.30]
$NP \rightarrow Det Nominal$	[.20]
$NP \rightarrow Nominal$	[.15]
$Nominal \rightarrow Noun$	[.75]
$Nominal \rightarrow Nominal Noun$	[.20]
$Nominal \rightarrow Nominal PP$	[.05]
$VP \rightarrow Verb$	[.35]
$VP \rightarrow Verb NP$	[.20]
$VP \rightarrow Verb \ NP \ PP$	[.10]
$VP \rightarrow Verb PP$	[.15]
$VP \rightarrow Verb NP NP$	[.05]
$VP \rightarrow VP PP$	[.15]
$PP \rightarrow Preposition NP$	[1.0]

#### Lexicon

 $\begin{array}{l} Det \rightarrow that \ [.10] \mid a \ [.30] \mid the \ [.60] \\ Noun \rightarrow book \ [.10] \mid flight \ [.30] \mid meal \ [.15] \mid money \ [0.5] \\ \mid flights \ [0.40] \mid dinner \ [.10] \\ Verb \rightarrow book \ [.30] \mid include \ [.30] \mid prefer \ [.40] \\ Pronoun \rightarrow I \ [.40] \mid she \ [.05] \mid me \ [.15] \mid you \ [.40] \\ Proper-Noun \rightarrow Houston \ [.60] \mid NWA \ [.40] \\ Aux \rightarrow does \ [.60] \mid can \ [.40] \\ Preposition \rightarrow from \ [.30] \mid to \ [.30] \mid on \ [.20] \mid near \ [.15] \\ \mid through \ [.05] \end{array}$ 



# Example PCFG: Augmented $\mathscr{L}_1$

Grammar	
$S \rightarrow NP VP$	[.80]
$S \rightarrow Aux NP VP$	[.15]
$S \rightarrow VP$	[.05]
$NP \rightarrow Pronoun$	[.35]
$NP \rightarrow Proper-Noun$	[.30]
$NP \rightarrow Det Nominal$	[.20]
$NP \rightarrow Nominal$	[.15]
$Nominal \rightarrow Noun$	[.75]
$Nominal \rightarrow Nominal Noun$	[.20]
$Nominal \rightarrow Nominal PP$	[.05]
$VP \rightarrow Verb$	[.35]
$VP \rightarrow Verb NP$	[.20]
$VP \rightarrow Verb \ NP \ PP$	[.10]
$VP \rightarrow Verb PP$	[.15]
$VP \rightarrow Verb NP NP$	[.05]
$VP \rightarrow VP PP$	[.15]
$PP \rightarrow Preposition NP$	[1.0]

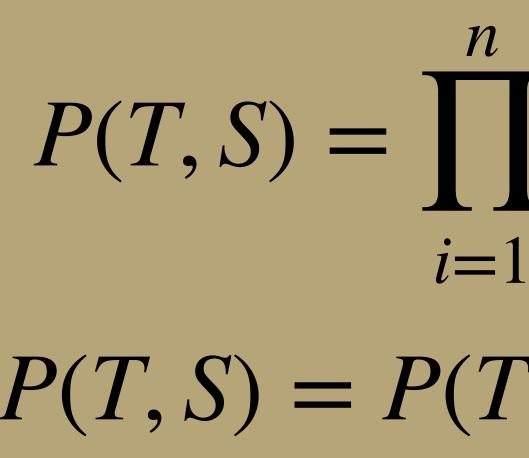
#### Lexicon

 $\begin{array}{l} Det \rightarrow that \ [.10] \mid a \ [.30] \mid the \ [.60] \\ Noun \rightarrow book \ [.10] \mid flight \ [.30] \mid meal \ [.15] \mid money \ [0.5] \\ \mid flights \ [0.40] \mid dinner \ [.10] \\ Verb \rightarrow book \ [.30] \mid include \ [.30] \mid prefer \ [.40] \\ Pronoun \rightarrow I \ [.40] \mid she \ [.05] \mid me \ [.15] \mid you \ [.40] \\ Proper-Noun \rightarrow Houston \ [.60] \mid NWA \ [.40] \\ Aux \rightarrow does \ [.60] \mid can \ [.40] \\ Preposition \rightarrow from \ [.30] \mid to \ [.30] \mid on \ [.20] \mid near \ [.15] \\ \mid through \ [.05] \end{array}$ 



## Disambiguation

- A PCFG assigns probability to each parse tree T for input S
- Probability of T: product of all rules used to derive T



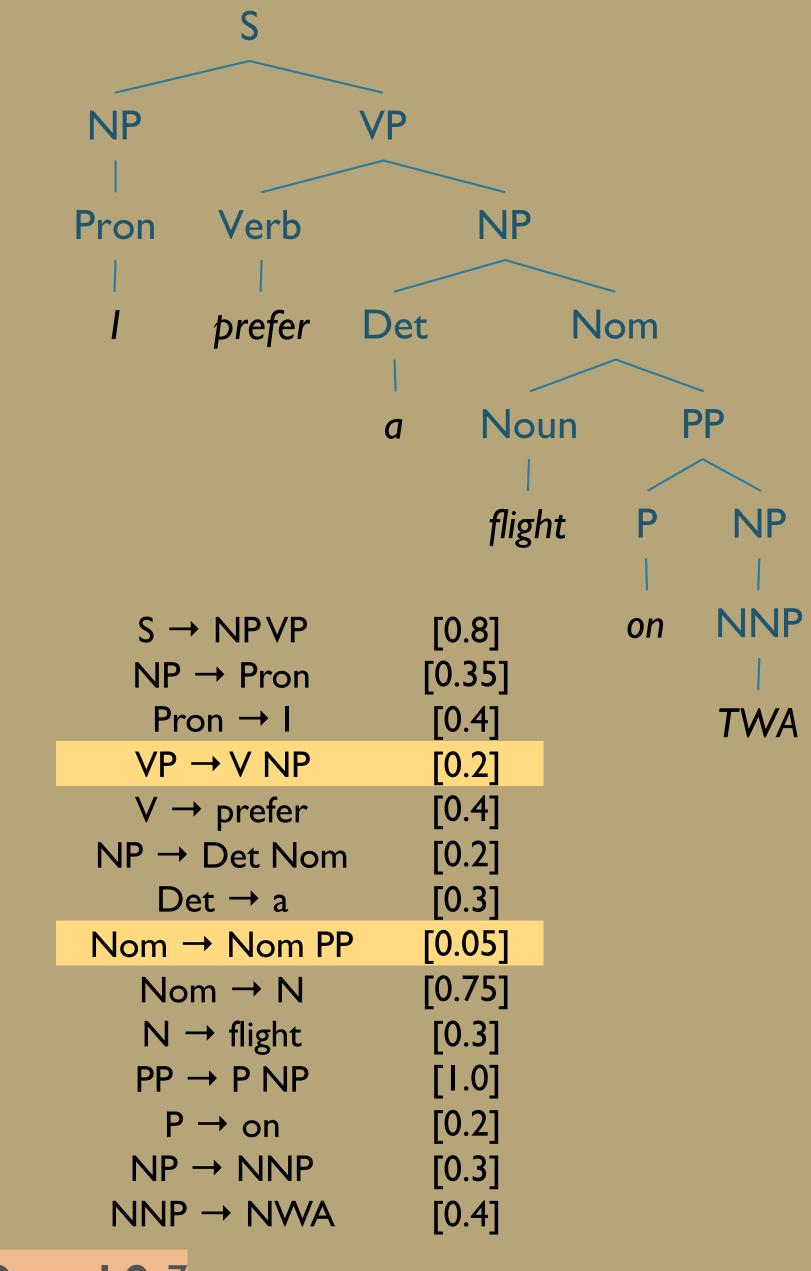
 $P(T,S) = \prod P(RHS_i | LHS_i)$  $P(T, S) = P(T)P(S \mid T) = P(T)$ 





	S						
NP	VP						
Pron	Verb	NP			PP		
1	þrefer	Det	Nom	P	NP		
		a	Noun	on	NNP		
			flight		TWA		
		$S \rightarrow N$ NP $\rightarrow$ Pron	Pron	[0.8] [0.35] [0.4]			
		$VP \rightarrow V$ $V \rightarrow F$	orefer		[0.1] [0.4]		
		Det Nom	→ N		[0.2] [0.3] [0.75]		
		$\begin{array}{c} N \rightarrow \\ PP \rightarrow \\ P \rightarrow \end{array}$	P NP on		[0.3] [1.0] [0.2]		
		NP → NNP →			[0.3] [0.4]		

#### ~I.452 × I0<sup>-6</sup>

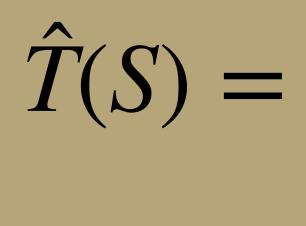


~1.452 × 10<sup>-7</sup>



# Parsing Problem for PCFGs

• Select T such that (s.t.)



• String of words *S* is *yield* of parse tree • Select the tree T that maximizes the probability of the parse

### $\hat{T}(S) = \arg \max P(T)$ T s.t. S=yield(T)











- Strategy of testing individual pieces of code in isolation
- Helps ensure:
  - Basic functionality in isolation
  - Complex functionality when individual components are combined
- In many industry jobs, you can't commit code without unit tests!

# Unit Testing





# Unit Testing in Python

- Many good tutorials on the web [here's one]
- In a nutshell:

from unittest import TestCase

**class** longTests(TestCase): def test three(self): length 3 rule = parse productions('A -> B C D')

target rules = parse productions('''A -> B X0

self.assertSetEqual(set(target rules),

XO -> C D''')set(fix long rules(length 3 rule)))



# Unit Testing in Python

• "nose" is a test running framework that will detect all test \* method functions python3 -m nose hw2.py

```
AssertionError: Items in the first set but not the second:
                           A \rightarrow B X0
                           X0 \rightarrow C D
         Items in the second set but not the first:
                            A \rightarrow B C
                     Ran 12 tests in 0.040s
```

FAILED (failures=1)



#### • Good practice:

• Save input that crashes your program for a unit test

# Unit Testing





