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## LCTG—Notes 2: Transformational and Computational Extensions of CFG

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## Bounded and Unbounded Dependency

- Natural Language Grammar is concerned with two kinds of construction involving *dependency* between elements of syntactic structure:
  - Those involving *bounded* dependencies:
    - Eg Binding and control are relations between elements of the *same tensed domain*:
      - a. *Gilbert* likes *himself*/showed *himself* a movie/\*thinks Hermione likes *himself*.
      - b. Gilbert persuaded *George* to *take a bath*/\*that Hermione advised to *take a bath*
  - Those involving *unbounded* dependencies: E.g. relative clauses relate nouns and verbs *across tensed clause boundaries*:
    - a. *A man who* Gilbert thinks he *likes*

2

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## Unbounded Dependency: The Relative Clause

- (1) The boys say that Hermione thinks that we are wasting our time.
- (2)
  - a. You should *sell that bike* soon.
  - b. *That bike* you should *sell* soon.
  - c. *That bike* I think you should *sell* soon.
  - d. *That bike* I heard they think you should *sell* soon
  - e. ...
- (3)
  - a. *Which bike* should you *sell* soon?
  - b. *Which bike* do they think you should *sell* soon?
  - c. ...

3

- (4)
  - a. Fred *likes that man*.
  - b. John likes the *man* [that Fred *likes*].
  - c. John likes the *man* [that Sally thinks [that Fred *likes*]].
  - d. John likes the *man* [that Sally thinks [that Fred sees[that Mary *likes*]]].
  - e. ...

4

## Context Free Base Generation Apparently Overgenerates

$S \rightarrow NP VP$   
 $NP \rightarrow \begin{cases} the N (Scomp) \\ t \\ \{John, Fred, Sally, Mary, \dots\} \end{cases}$   
 $VP \rightarrow \begin{cases} TV NP \\ CV Scomp \end{cases}$   
 $Scomp \rightarrow that S$   
 $N \rightarrow \{man, woman, boy, girl, \dots\}$   
 $TV \rightarrow \{see, like, loath, \dots\} + s$   
 $CV \rightarrow \{see, know, dream, \dots\} + s$

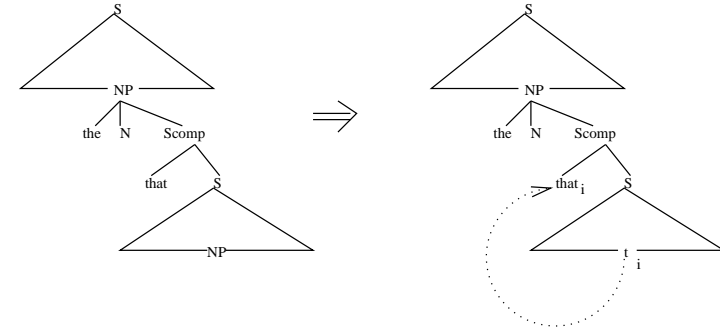
- (5) a. Fred met the man that Sally saw on Tuesday.  
 b. \*Fred thinks that Sally saw on Tuesday.
- (6) a. \*Fred met the man that Sally saw John on Tuesday.  
 b. I think that Sally saw John on Tuesday.

5

## Two Ways of Looking at the Problem

### 1 Generic Transformational Generative Grammar

(Chomsky 1957; 1965; 1975; 1981; 1995 *passim*)



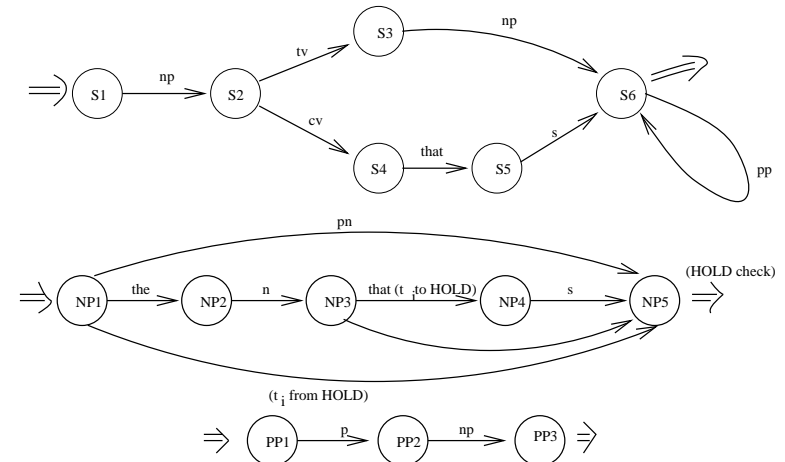
6

## Two Ways of Looking at the Problem #2: the ATN

Regular Grammar  $\equiv$  Finite-State Automaton (FSA)  
 Context-Free Grammar  $\equiv$  Push-Down Automaton (PDA)  
 (FSA + Stack)  
 Transformational Grammar  $\equiv$  Augmented Transition Network (ATN) Grammar  
 (PDA + memory registers, conditions and actions on transition arcs)  
 The automata theoretic power of an ATN depends on the character of the registers. If any register is a (second) stack then we potentially attain Turing-machine power.

7

## Augmented Recursive Transition Network Grammars (ATN)



8

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## Transformations as Operations on Registers

- Bounded constructions were expressed as operations on registers.
- For example, when the ATN encountered a reflexive it looked for a binder in the SUBJ register, or some other.
- Similarly, a controlled infinitive looked for its subject in the matrix SUBJ or OBJ
- Unbounded constructions were expressed as operations on a unique register called HOLD.
- When it encountered a relative pronoun, it entered a pointer to it in HOLD, without worrying about where it would end up. When it needed a NP that wasn't there, it used a pointer from HOLD, without caring where it came from

9

### 3 Nested Dependencies and Violin and Sonata Sentences

- (9) a. a violin which the Moonlight Sonata is easy to play on  
b. \*a sonata which this Stradivarius violin is easy to play on

### 4 Another Asymmetry: The Fixed Subject or “\*that-t” Constraint

- (10) a. a man who(m) I think that I like  
b. \* a man who(m) I think that likes me

### 5 The Clause-non-final Incomplete Constituent Constraint

- (11) a. I put the book on the table  
b. I put on the table the very heavy book  
c. The table that I put the book on  
d. \*The table that I put on the very heavy book

11

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## Constraints on the Relative Construction

- We have been trying to capture in our grammar the fact that dependency is unbounded in relative clauses (Woods 1973: “the constituent extracted can be arbitrarily deep in nested embedded clauses.”)
- But there are curious and arbitrary-seeming restrictions on exactly where an unbounded dependency can occur. Ross’s paper is all about this.

### 2 Nested Dependencies and Ross’s Complex NP Constraint

- (7) a. I met a man that ate a cake.  
b. ? a cake that I met a man who ate
- (8) a. I bought a cake that the man ate  
b. \*a man who(m) I bought a cake that ate

10

### 6 Ross’s Coordinate Structure Constraint (CSC)

- (12) a. This man loves animals and he dislikes children.  
b. Animals love this man and children dislike him.  
c. Animals love this man and he dislikes children.
- (13) a. \* a man who(m) loves animals and he dislikes children  
b. \* a man who(m) animals love and children dislike him

### 7 The “Across the Board” (ATB) Exception to CSC

- (14) a. a man who(m) animals love and children dislike.  
b. a man who loves animals and dislikes children.

### 8 The Same Case Condition on the ATB Exception to CSC

- (15) a. \*a man who dislikes children and animals love.  
b. \* a man who(m) animals love and dislikes children.

12

## 9 Conclusion

- The existence of all these unexplained constraints on unbounded dependencies calls for explanation, rather than stipulation.
- One place to look for an explanation is in the automaton itself. Maybe something less powerful than a Turing machine would *predict* these constraints.
- In particular the fact that *multiple* unbounded dependencies often require *nesting* dependences is suggestive.
- Maybe we can make the hold register as a stack without making it a *second* stack, using the *same* stack for both purposes?