Comments on Left-Corner

- Mixed data-driven and hypothesis driven approaches
  - Eager corresponds to composition of partial structures

- **Arc Standard**: less ambiguity
  - attach when constituents are complete: safer
  - delayed attachment means more is kept on the stack

- **Arc Eager**: less memory
  - early composition reduces stack growth
  - eager attachments are less bottom-up
Ambiguity in Parsing

• Rule selection: *what if more than one rule can be selected?*
  • Local ambiguity: a parse derivation may fail later
  • Global ambiguity: multiple parses can succeed

• How can we handle local and global ambiguities during parsing:
  • Backtracking
  • Parallelism
  • Determinism
  • Underspecification
Backtracking Parsers

- Parsing is a sequence of rule selections

- If at one point, more than one rule can be applied, this is called a choice point
  - Make a decision, based on some selection rule
  - If subsequently parsing ‘blocks’, return to a choice point and re-parse from there

- Which choice point to return to?
  - usually the last, why?
  - what other choice point selection rules could be used

Backtracking: an example

Bill reads

Bill reads
Parallel Parsers

• Build parse trees through successive rule selections

• If more than one rule may be applied, create a new parse derivation for each possibility

• Pursue all parses in parallel

• If any of the parses ‘blocks’, discard it

• Because of multiple local ambiguities, the number of parallel derivation grows exponentially

• Bounded parallelism: pursue a fixed number

• How do we choose which ones to keep?

Parallel: an example

Bill reads
Theories of Sentence Processing

- Explanatory and descriptive goals

- Theories of parsing typically determine …
  - what architecture is assumed: modular? symbolic? …
  - what mechanism is used to construct interpretations?
  - which information sources are used by the mechanism?
  - which representation is preferred/constructed when ambiguity arises?

- Linking Hypothesis: Relate theory/model to observed measures
  - Preferred sentence structures should have faster reading times in the disambiguating region than dispreferred

Garden-Path Theory: Frazier

- What architecture is assumed?
  - Modular syntactic processor, with restricted lexical (category) and semantic knowledge

- What mechanisms is used to construct interpretations?
  - Incremental, serial parsing, with reanalysis

- What information is used to determine preferred structure?
  - General syntactic principles based on the current phrase structure

- Linking Hypothesis:
  - Parse complexity and reanalysis cause increased RTs
The Garden Path Theory (Frazier)

Which attachment do people initially prefer?

First Strategy: Minimal Attachment
NP/S Complement Ambiguity

Second Strategy: Late Closure

- **Late Closure**: Attach material into the most recently constructed phrase marker

```
S
 / \   \   \   \   \  \
NP   VP  The student V  NP  The student V  S
   \    \  knew  the solution ... knew  NP  VP
        \                                    the solution ...
```
Well-known local ambiguities

NP/VP Attachment Ambiguity:
“The cop [saw [the burglar] [with the binoculars]]”
“The cop saw [the burglar [with the gun]]”

NP/S Complement Attachment Ambiguity:
“The athlete [realised [his goals]] last week”
“The athlete realised [[his goals] were unattainable]”

Clause-boundary Ambiguity:
“Since Jay always [jogs [a mile]] [the race doesn’t seem very long]”
“Since Jay always jogs [[a mile] doesn’t seem very long]”

Reduced Relative-Main Clause Ambiguity:
“[[The woman [delivered the junkmail on Thursdays]]”
“[[The woman [delivered the junkmail]] threw it away]”

Relative/Complement Clause Ambiguity:
“The doctor [told [the woman] [that he was in love with her]]”
“The doctor [told [the woman [that he was in love with]] [to leave]]”

Summary of Frazier

• Parsing preferences are guided by general principles:
  • Serial structure building
  • Reanalyze based on syntactic conflict
  • Reanalyze based on low plausibility (“thematic fit”)

• Psychological assumptions:
  • Modularity: only syntactic (not lexical, not semantic) information used for initial structure building
  • Resources: emphasizes importance of memory limitations
  • Processing strategies are universal, innate
Grammar-Based Strategies

- Not concerned with representation or ‘form’, but defined in terms of syntactic ‘content’

- Strategies are modular, but ‘knowledge-based’

- Motivation: strategies are derived from the purpose of the task, not e.g. computational efficiency

- Closer competence-performance relationship

- Defined w.r.t. to deeper syntactic notions: less sensitive to minor structural details (cf. Minimal Attachment)


Pritchett (1992)

- Incrementally establish primary syntactic dependencies

- **Theta-Criterion:** (GB theory, also in LFG + HPSG)

  - Each argument must receive exactly one theta-role, and each theta role must be assigned to exactly one argument

- Consider:

  *The boy put the candy on the table in his mouth*
Pritchett (1992)

- **Theta-Attachment:**
  - Maximally satisfy the theta-criterion at every point during processing, given the maximal theta-grid of the verb

- **Theta Reanalysis Constraint:**
  - Reanalysis of a constituent out of its theta-domain results in a conscious garden-path effect

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**Theta-Reanalysis: Easy**

- Reanalysis to a position within the original theta-domain is easy.
Theta-Reanalysis: Difficult

- Reanalysis to a position outside the original theta-domain is difficult.

Pritchett: Another example

- "Without her contributions the orphanage closed"
  - ‘Without’: a Prep with a single thematic role
  - ‘her’: an determiner of an unseen NP head, or a Full NP (Pronoun) [Theta-attach]
  - ‘contributions’: head of a new NP, with no role, or combine with ‘her’ for a Full NP [Theta-attach]
  - “Without her contributions failed to come in”
    - ‘contributions’ becomes subject of ‘failed’, violating [Theta-reanalysis Constraint]
Well-known local ambiguities

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Grammar-Based (cont’d)

- Theta-Attachment: reliance on theta-grids means it’s head driven
- O.k. for English, but not incremental for head-final languages
- Same problem for Abney (1989), and other head-driven models
- Argument-Attachment: Attach constituent into potentially role-receiving positions (Crocker, 1992)
Pritchett’s Theory (1992)

- **What architecture is assumed?**
  - Modular lexico-syntactic processor with syntactic and thematic role features

- **What mechanisms is used to construct interpretations?**
  - Incremental, serial parsing, with reanalysis

- **What information is used to determine preferred structure?**
  - Grammar principles and thematic role information

- **Linking Hypothesis:**
  - TRC violation causes garden-path, reanalysis without TRC is relatively easy

Long Distance Dependencies

- **Wh-Fillers:**
  - *Who<sub>i</sub> did Fred tell Mary e<sub>i</sub> left the country?*  
    - dispreferred
  - *Who<sub>i</sub> did Fred tell e<sub>i</sub> Mary left the country?*  
    - preferred

- **Subject-Relative preference:**
  - *I met the man<sub>i</sub> that John likes e<sub>i</sub>.*  
    - dispreferred
  - *I met the man<sub>i</sub> that e<sub>i</sub> likes John.*  
    - preferred

- **Active Filler Strategy:** ("Gap as a first resort")
  - When a filler has been identified, rank the possibility of assigning it to a gap above all other options.
Further observations …

• Filled-Gap effect:
  
  • My brother wanted to know who\textsubscript{i} Ruth will bring (*e\textsubscript{i}) us home to e\textsubscript{i} at Christmas
  
  • My brother wanted to know if Ruth will bring us home to Mom at Christmas
  
  • Found an increased reading time at us, interpreted this as surprise
  
• Intuitively easy:
  
  • Who\textsubscript{i} (e\textsubscript{i}) did you want (e\textsubscript{i}) Mother to bake (e\textsubscript{i}) a cake for e\textsubscript{i}?
  
  • ... despite 3 possible earlier gap locations

Gaps versus Dependencies

• Consider:
  
  • [In which tin\textsubscript{i} did you put the cake e\textsubscript{i}?] \hspace{1cm} \textbf{Gap account}
  
  • [In which tin\textsubscript{i} did you put the cake?] \hspace{1cm} \textbf{Dependency account}
  
• If keeping the filler in memory causes difficulty, we can compare:

  \begin{align*}
  [\text{In which tin\textsubscript{i} did you put the cake that your little sister baked for you e\textsubscript{i}?] & \hspace{1cm} \textbf{Easy} \\
  \left[\text{Which tin\textsubscript{i} did you put the cake that your little sister baked for you in\textsubscript{i} e\textsubscript{i}?} & \hspace{1cm} \textbf{Hard}
  \end{align*}

• Intuitive support for the dependency account, and against gaps.
Other evidence

- Implausibility detected immediately at the verb, as shown by increased reading times.
- That's the [pistol/garage], with which the heartless killer shot, the hapless man yesterday afternoon.
- Garnsey et al (1998) found an N400 at the verb, for the implausible condition.
- The businessman knew which [customer/article], the secretary called at home.
- Pickering and Barry (1996) argued that a dependency-based account was preferable to a trace-based account.

Parsing in 2 dimensions

- Gaps don’t exist in the input, so we needn’t wait until they are found.
- We can associate a filler & gap as soon as the structure licenses it:

Consider: Den Hund; sahj Maria e; e;.
Summary

• Frazier: early parsing decisions driven by purely syntactic heuristics
  • MA and LC were argued to be by-products of a race mechanism

• Eager dependency-formation plays a strong role in driving parsing decisions:
  • Pritchett's theta-attachment
  • Local coherence trumps global syntactic parsing constraints
  • Active-Filler Hypothesis
  • Pickering & Barry's Dependency Association account