Quick Recap

- 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
Long Distance Dependencies

• Wh-Fillers:
  
  • *Who* did Fred tell *Mary* *e₁ left the country?* **dispreferred**
  
  • *Who* did Fred tell *e₁ Mary* *left the country?* **preferred**

• Subject-Relative preference:

  • *I met the man* that *John* *likes e₁.* **dispreferred**
  
  • *I met the man* that *e₁ 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* *Ruth* *will bring (*e₁) us home to e₁ 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* (*e₁*) *did you want (e₁) Mother* *to bake (e₁) a cake for e₁?*
  
  • *... despite 3 possible earlier gap locations*
Gaps versus Dependencies

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

  \[\text{[In which tin]}i \text{ did you put the cake that your little sister baked for you } e_i?\]

  \[\text{Easy}\]

  \[\text{[Which tin]}i \text{ did you put the cake that your little sister baked for you in } e_i?\]

  \[\text{Hard}\]

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

Other evidence

• Implausibility detected immediately at the verb, as shown by increased reading times.

  \[\text{That's the [pistol/garage]}_i \text{ with which the heartless killer shot}_i \text{ the hapless man } e_i \text{ yesterday afternoon.}\]

• Garnsey et al (1998) found an N400 at the verb, for the implausible condition

  \[\text{The businessman knew which [customer/article]}_i \text{ the secretary called } e_i \text{ at home}\]

• Pickering and Barry (1996) argued that a \textit{dependency-based account} was preferable to a \textit{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* *sah* *Maria.*

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]]"
Deterministic Parsing

- Alternative: ensure only one possible parsing action at any point in parsing:
  - Avoid/delay rule selection until it is fully determined. How?
    - bottom up (e.g. S/R or LR) **plus lookahead** [Marcus; Berwick & Weinberg; Abney]

- Advantage: very fast, clear predictions

- Disadvantages:
  - not fully incremental (up to 3 *constituents* of look-ahead)
  - unsuccessful for head-final languages
  - wrong predictions: e.g. no gradedness of processing difficulty

Monotonic Parsing

- Inspired by determinism and reanalysis:
  - many local ambiguities seem to cause little difficulty
  - contra predictions of naive backtracking
  - Gorrell; Weinberg; Sturt & Crocker

- Provides a richer set of ‘tree-building’ operations which means destructive backtracking is not always required

- Predicts ‘reanalysis’ **outwith** these operations to be difficult
Talking about Talking about Trees

• Traditional theories locate reanalysis in the parser: “re-parsing”

• Can local ambiguity be handled using underspecified representations?
  • Representations which allow some ambiguity to remain, and be later removed without (destructive) re-parsing.

• Description-Theory: (Marcus, Hindle & Fleck, 1983)
  • Uses tree descriptions, not trees: e.g. dominance and precedence
  • Permits immediate interpretation, but allows insertion of nodes & branches

Monotonic Parsing [Gorrell; Sturt & Crocker]

• Trees are described as a set of nodes, and a set of precedence and dominance relations:
  • John knows Mary

\[
\begin{align*}
S \quad \downarrow \\
\quad \downarrow \\
NP1 & \quad VP \\
\quad \downarrow \\
John & \quad V \\
\quad \downarrow \\
& \quad NP2 \\
& \quad {\text{knows}} \\
& \quad Mary
\end{align*}
\]

\{\text{dom}(S,NP_1), \text{dom}(S,VP), \text{dom}(S,V), \text{dom}(S,NP_2), \text{prec}(NP_1,VP), \text{dom}(VP,V), \text{dom}(VP,NP_2), \text{prec}(V,NP_2) \ldots\}\]
Properties of Trees

- Single root condition: a single root node dominates all nodes
  \[ \exists x \forall y \cdot \text{dom}(x, y) \]
- Exclusivity condition: no two nodes can stand in dom & prec relations
  \[ \forall x, y \cdot \text{prec}(x, y) \lor \text{prec}(y, x) \iff \neg \text{dom}(x, y) \land \neg \text{dom}(y, x) \]
- Inheritance: nodes inherit precedence properties of their ancestors
  \[ \forall w, x, y, z \cdot \text{prec}(x, y) \land \text{dom}(x, w) \land \text{dom}(y, z) \rightarrow \text{prec}(w, z) \]
- \text{dom} and \text{prec} are transitive relations
- \text{dom} is reflexive, \text{prec} is irreflexive

Constraints on the Model

- **Strict incrementality**: words are connected to the tree description as they are encountered
- **Coherence**: tree properties must always be satisfied, the tree must be grammatically licensed
- **Full specification of nodes**: no features on nodes (e.g. bar-level) can be left unspecified
- **Informational monotonicity**: the tree description at state \( n \) is a subset of the description at state \( n+1 \)
- **Obligatory assertion of precedence**: precedence must be specified for sisters
Monotonic Parsing and Reanalysis

- **Easy**: *Monotonic* reanalysis  
  “John knows Mary is smart”

- **Hard**: *Non-monotonic* reanalysis  
  “While John walked the dog barked”

How does the parser *actually* work?

- The monotonic parser uses precomputed tree descriptions (e.g. for lexical items), and “macro” operations which meet the constraints.

- Non-monotonic operations are not permitted.

- Easy reanalysis parsing is “monotonic”.

- Difficult reanalysis, when tree-descriptions are changed non-monotonically.

Monotonic Parsing Operation

- Tree-lowering: “John knows Mary … “  
  “John knows Mary is smart”

\[
\{\text{dom}(S,\text{NP1}), \text{dom}(S,\text{VP}), \text{dom}(S,\text{V}), \text{dom}(S,\text{NP2}), \text{prec}(\text{NP1},\text{VP}), \text{dom}(\text{VP},\text{V}), \text{dom}(\text{VP},\text{NP2}), \text{prec}(\text{V},\text{NP2}), \text{dom}(\text{VP},\text{S2}), \text{dom}(\text{S2},\text{NP2}), \text{prec}(\text{NP2},\text{VP2}) \ldots \} \]
Theta-Reanalysis: Easy

• Reanalysis to a position within the original theta-domain is easy.

Non-Monotonic Parsing

• Predicting difficult reanalysis: While John walked the dog … barked.

… \( \text{dom}(\text{VP}, \text{NP}_2) \) … \textbf{but} … \( \text{dom}(\text{VP}, \text{NP}_2) \) & \( \text{prec}(\text{VP}, \text{NP}_2) \) …
Theta-Reanalysis: Difficult

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

Parsing Operations: Attachment

- Left attachment:

- Right attachment:
TAG Adjunction

- The operations of the monotonic parser resemble those of Tree Adjoining Grammar.

Tree Lowering
Psycholinguistic Evidence

- Are there really two types of reanalysis?
  - **NP/S (A):** "The woman saw the famous doctor had been drinking"
  - **NP/Z (A):** "Before the woman visited the famous doctor had been drinking"
  - **NP/S (U):** "The woman saw that the famous doctor had been drinking"
  - **NP/Z (U):** "Before the woman visited, the famous doctor had been drinking"

- All verbs are biased (BNC) towards NP complement
  - To make sure the object attachment is initially adopted, forcing reanalysis
  - Plausibility of the direct object analysis is similar (pre-test).


Results

- Reading times: Region 3
  
  "The woman / saw the famous doctor / had been drinking / all day"

![Reading Time Graph](image)

- Main effects of construction type, ambiguity, and a significant interaction
- GP effect: NP/Z (400ms) vs. NP/S (87ms)
Search in Parsing/Reanalysis

- (Some) reanalysis is simply monotonic attachment: e.g. tree-lowering.
- What if there are multiple such “lowering” attachments
- Consider a double NP/S ambiguity:
  - “I know the man who believes the countess killed herself”
  - “I know the man who believes the countess killed himself”
- Which is easier?
- How does the parser search for an attachment?

The Trees
Search

- English appears to use a bottom-up search strategy for attachment
  - late closure, recency
  - Someone shot the servant of the actress who was on the balcony

Possibly other influences:

- Verb bias? Predicate proximity (Gibson)?

Japanese seems to be top-down

- Head final, left-branching language (Sturt & Crocker, 1996)

Summary of Reanalysis

- Frazier: no clear account
- Pritchett: cost determined by syntactic nature of reanalysis (TRC)
- Monotonic Parsing:
  - Representations allow for some kinds of local ambiguity
    - Some reanalysis is monotonic (easy), some is destructive (difficult)
  - Similar in some respects to Pritchett's theory (of reanalysis)
  - Search mechanism still required when multiple reanalyses is possible
Summary of Syntactic Models

• Syntactic Parsing Theories:
  • Frazier: emphasis on syntactic structure/form
  • Pritchett: emphasis on syntactic dependencies/content

• Assume serial, incremental parsing. Reanalysis causes difficulty

• Preference to associate fillers with role-assigners immediately

• Monotonic models enable some local ambiguities to be revised without destructive reanalysis
  • distinguish easy and difficult “garden paths”

A Puzzle

• Sometimes local thematic assignment appears to violate global parse:
  • [A/R] The coach smiled at the player tossed a frisbee by the ...
  • [U/R] The coach smiled at the player thrown a frisbee by the ...
  • [A/U] The coach smiled at the player who was tossed a frisbee by the ...
  • [U/U] The coach smiled at the player who was thrown a frisbee by the ...

• We might expect to see:
  • Main effect of verb ambiguity: if ambiguous verbs are difficult
  • Main effect of structure ambiguity: if ambiguous RRCs are difficult
But: they found an interaction!

Implies that an “impossible” parse influences the verb’s difficulty

• These results are problematic for theories requiring global contextual consistency (e.g. Frazier, 1987; Gibson, 1991, 1998)