1 Global ambiguity

\[
S \rightarrow \text{NP VP} \\
\text{NP} \rightarrow \text{the spy} \\
\text{NP} \rightarrow \text{the cop} \\
\text{NP} \rightarrow \text{NP PP} \\
\text{PP} \rightarrow \text{with binoculars} \\
\text{VP} \rightarrow \text{saw NP} \\
\text{VP} \rightarrow \text{saw NP PP}
\]

(Rayner, Carlson, and Frazier, 1983)

Figure 1: PP attachment grammar

- modifiers are sisters
- noun phrase “adjunction” rule says this PP modifies this NP
- verb phrase likewise has optional prepositional phrase (PP) complement

Syntactic analyses suggest semantic content:

\begin{enumerate}
\item [1] [S [NP the spy] [VP saw [NP the cop] [PP with binoculars]]] binoculars help the spy do his seeing
\item [2] [S [NP the spy] [VP saw [NP [NP the cop] [PP with binoculars]]] binoculars are a distinguishing possession of the cop
\end{enumerate}

Consider the case of a PP modifying an NP:

\begin{enumerate}
\item [3] a. Put the block [in the box on the table] \\
  b. Put the [block in the box] on the table
\item [4] a. Put the block in [[the box on the table] in the kitchen] \\
  b. Put the block in [the box [on the table in the kitchen]] \\
  c. Put [[the block in the box] on the table] in the kitchen \\
  d. Put [the block [in the box on the table]] in the kitchen \\
  e. Put [the block in the box] [on the table in the kitchen]
\end{enumerate}

As the number of PPs increases, the number of possible analyses increases as the Catalan numbers

\[
\text{Cat}_n = 2, 5, 14, 42, 132, 469, 1430, 4862, \ldots
\]

\[
= \binom{2n}{n} - \binom{2n}{n-1}
\]

(Church and Patil, 1982)
2 Local ambiguity

We take in words serially, one at a time – and yet we have some idea what people mean before they finish speaking. For the human sentence processing mechanism to work in this eager fashion, assumptions need to be made about the intended structure before the end of the sentence.

(5) The dog walked to the park had been chewing the bone.

If these structural assumptions turn out to be wrong, the processor has been led up the garden path. Sentence like 5 are known as garden-path sentences because of their temporary ambiguity.

(6)

(7)

1. the band started in suburban Chicago gained popularity in New York
2. the nurses switched to overnight duty became irritable during the day
3. the inmates crowded in the hallway had an air of misery
4. the vendors closed for winter will re-open in the spring
3 Methods

A Garden Path effect is the difference between the temporarily ambiguous sentence and an unambiguous control sentence.

(8) a. The dog walked to the park had been chewing the bone.
    b. The dog that was walked to the park had been chewing the bone.

self-paced reading subjects take much more time at “...had been chewing...”

eye tracking subjects look longer in the region “...had been chewing...”, look back to earlier regions

the same methods can be used to investigate sentences that are grammatical, yet abnormally difficulty to understand

the reporter disliked the editor

(9) ? the reporter [ who the senator attacked ] disliked the editor
   *? the reporter [ who the senator | who John met | attacked ] disliked the editor
(10) √ John met the senator [ who attacked the reporter | who disliked the editor ]

4 The Garden Path Model of human sentence processing

Lyn Frazier and Janet Fodor’s (1978) Garden Path Model proposed two heuristic principles that seem to guide the human processor’s choice of phrase structure rule.

Minimal Attachment Do not postulate any potentially unnecessary nodes

Late Closure aka Right Association If grammatically permissible, attach new items into the clause or phrase currently being processed

Consequences of Minimal Attachment

• The main verb reading (in 6) requires extra TP, DP, CP and nodes compared to the reduced relative. The feeling of confusion at “...had been chewing” is because the parser must go back and re-analyze at that point.

• The PP-attachment ambiguity (from grammar 1) is explained by that fact that the VP attachment (i.e. VP → saw NP PP) uses one less layer of NP recursion, and is therefore preferred.

Consequences of Late Closure

• The direct object reading (vs. intransitive “jogs”) is correctly predicted for

(11) Since Jay always jogs a mile this seems like a short distance to him versus
(12) Since Jay always jogs a mile seems like a short distance to him

• Low attachment is correctly predicted for adverbs like “yesterday”

(13) Joyce said Tom left yesterday versus
(14) Joyce said $E = MC^2$ yesterday
5 Informational constraints

Particular properties of words have a stronger effect on sentence understanding than the Garden Path model would suggest.

**Lexical Bias** (Ford, Bresnan, and Kaplan, 1982)

(15) Joe bought the book for Susan
MA predicts that "for Susan" is a beneficiary of "bought", not a modifier of "the book"

(16) Joe included my gift for Susan
Same syntactic structure, but the preferred reading is that "for Susan" is now a modifier of "my gift"

Result: with some verbs, the processor overrides general principles like MA.

**Animacy** (Ferreira and Clifton, 1986) (Trueswell, Tanenhaus, and Garney, 1994)

(17) The witness examined by the lawyer was useless
(18) The evidence examined by the lawyer was useless

Result: implausibility of evidence examining a lawyer makes garden path effect go away in 18. In 5, animate entities like dogs are likely to be the agent, not the patient.

**Frequency** (MacDonald, 1994)

(19) The rancher knew that the nervous cattle \{
\begin{align*}
\text{pushed} \\
\text{moved} \\
\text{driven}
\end{align*}
\} into the crowded pen were afraid of the cowboys

Result: "pushed" frequency-biased toward transitive leads more inductably up the garden path than does "moved" frequency-biased toward intransitive. In 5, the simple past form of walk is more frequent than the past participle.

References


