Processing Quantifiers in Object Position

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Realtime studies of semantic composition focus on the time course and resource demands of semantic coercion.

”coercion” = a basic/preferred meaning is enriched/changed in favor of a richer/less accessible meaning due to compositional properties of the local environment.

(1) The boy started/saw the fight/puzzle ...
   cf. Traxler, et al. 2002

(2) Because it was cold, the team sprinted/huddled into/inside the gym ...
   cf. Acland et al. 2004
The problem of quantifiers in object position.

Quantifiers in object position constitute one of the most well-known cases of syntax/semantics mismatch. (Montague’73)

- Quantifiers do not refer.
- Quantifiers can appear in internal argument positions that are reserved for referring expressions.
- "Quantifier-hood" needs to be syntactically visible.

(3) Every student likes Mary.
(4) Mary likes every student.
Statement of the problem within type-theory.

- Quantifiers in subject position take the VP as argument.
- Quantifiers in object position cannot combine with the verb.

(1)\[\begin{array}{c}
\text{IP}_t \\
| \\
| \\
\text{VP}_{e,t} \\
| \\
\text{NP}_{e,t} \\
| \\
\text{D}_{e,ett} \\
\end{array}\]

Every student likes Mary

(2)\[\begin{array}{c}
\text{IP}_{???
| \\
| \\
\text{VP}_{???
| \\
\text{D}_e \\
\text{NP}_{e,t} \\
\text{V}_{e,et} \\
\text{Mary} \\
\end{array}\]

Mary likes every student
Possible Solutions.

There are at least 3 types of solutions that have been proposed in the literature.

- Typeshifting (e.g. Montague’73)
- Quantifier Raising (e.g. May’77)
- $\epsilon$-Calculus (e.g. Kempson et al.’01)
Possible Solutions.

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Type-Shifting (e.g. Montague’73).

- The type of the verb (or determiner) is shifted so that it can combine directly with a quantifier (or verb).

\[\text{likes}_1 = \lambda x : x \in D_e . \lambda y : y \in D_e . y \text{ likes } x.\]

\[\text{likes}_2 = \lambda f : f \in D_{\langle \text{ett} \rangle} . \lambda y : y \in D_e . f \left( \lambda x . \left[ \text{likes}_1 \right] (x)(y) = 1 \right) = 1\]
The quantifier is moved by a syntactic operation to the top of the clause just like quantifiers in PL are always prefixed.

(4)  

\[
\begin{align*}
\text{Every student} & \quad \lambda x \quad \text{IP}_t \\
\text{Mary} & \quad \text{IP}_t \\
\text{likes}_{e,et} & \quad x_e
\end{align*}
\]
Motivation

Processing of Quantifiers in Object Position

Conclusion

Realtime studies of semantic composition
Quantifiers in Object position
Possible Solutions

$\epsilon$-Calculus (e.g. Kempson et al. ’01).

Assume that the semantic complexity of quantifiers is not visible to the compositional engine.

- $\epsilon$-Calculus treats quantifiers *syntactically* like any other DP.
- Interpreting quantifiers in object position is as complex as interpreting quantifiers in subject position.
- Quantifiers in object position do NOT constitute a syntax-semantics mismatch.

- Realtime processing effects of quantifiers in object positions undermine the $\epsilon$-Calculus solution.
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- $\epsilon$-Calculus treats quantifiers *syntactically* like any other DP.
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- Quantifiers in object position do NOT constitute a syntax-semantics mismatch.

- Realtime processing effects of quantifiers in object positions undermine the $\epsilon$-Calculus solution.
If the increased complexity of quantifiers in object position is visible to the parser we expect that . . .

- Subject QPs are easier to process than object QPs.
QPs can be a factor in local ambiguity resolution.

Example: NP/S Ambiguity

(1) The judge believed every witness ...
   a. ...was at the scene of the crime.
   b. ...who was at the scene of the crime.

A direct comparison of (1)a and b won’t be informative!
NP/S-Ambiguity with Quantifiers.

- **2x2 Design: "Determiner by Attachment"

  (1) The judge believed **the** witness ...
      a. ...was at the scene of the crime.
      b. ...who was at the scene of the crime.

  (2) The judge believed **every** witness ...
      a. ...was at the scene of the crime.
      b. ...who was at the scene of the crime.

- We expect an interaction between Determiner type and Attachment type: Object QPs should be relatively harder.
To get a handle on possible interference from verb preferences (cf. Trueswell et al.’93, etc.) we ran two versions of the experiment:

- Experiment 1: S-biased verbs
- Experiment 2: NP-biased verbs

Methods

- 20 undergraduates from Claremont Colleges, native speakers of English.
- Single word, self-paced, moving window reading paradigm.
- 32 target items (8 in each cell), 92 filler items.
- Each sentence was followed by a comprehension question.
Experiment 1: S-bias

Materials

- 4 versions of target sentences were constructed as exemplified below.
- S-biased verbs were chosen from Trueswell et al.’93 (verb bias was checked against Brown and Wall Street Journal Corpus of Penn Tree Bank).

(1) The nun claimed the child ...
   a. ...who was abused and malnourished.
   b. ...was abused and malnourished.

(2) The nun claimed every child ...
   a. ...who was abused and malnourished.
   b. ...was abused and malnourished.
Analysis

- Residual reading times were calculated from sentences whose follow-up question was answered correctly.
- RRTs were trimmed by 3 stdv across subjects.
- Repeated Measures ANOVA on mean RRTs (word by word and across regions).
Residual Reading Times: S-Bias

Sentential Bias

- The/Was
- The/Who
- Every/Was
- Every/Who

Res.RTs

the  nun  claimed  the/every  child  who/was  word1  word2  word3

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Residual Reading Times: S-Bias

Sentential Bias

*0.036  *0.045

The/Was  The/Who  Every/Was  Every/Who

Res.RTs

the  nun  claimed  the/every  child  who/was  word1  word2  word3
Residual Reading Times: S-Bias

Sentential Bias

* .043

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Residual Reading Times: S-Bias

Sentential Bias

- The/Was
- The/Who
- Every/Was
- Every/Who
Residual Reading Times: S-Bias

Sentential Bias

Res.RTs

the  run  claimed  the/every  child  who/was  word1  word2  word3

The/Was  The/Who  Every/Was  Every/Who

*.01
Summary of Results: Experiment 1

Findings of Experiment 1

- Main effect of Determiner Type one word after the determiner.
- Interaction as early as one word after disambiguation.
- Interaction stable over region from disambiguation to 3 words after.
Experiment 2: NP-bias

Materials

- Sentence frames as in Experiment 1.
- NP-biased verbs were chosen from Trueswell et al.'93 (verb bias was checked against Brown and Wall Street Journal Corpus of Penn Tree Bank).

(1) The nun remembered the child ...
   a. ...who was abused and malnourished.
   b. ...was abused and malnourished.

(2) The nun remembered every child ...
   a. ...who was abused and malnourished.
   b. ...was abused and malnourished.
Residual Reading Times: NP-Bias

DO Bias

<table>
<thead>
<tr>
<th>the</th>
<th>nun</th>
<th>remembered</th>
<th>the/every</th>
<th>child</th>
<th>who/ was</th>
<th>word1</th>
<th>word2</th>
</tr>
</thead>
</table>

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Residual Reading Times: NP-Bias

DO Bias

*0.005

The/\Was
The/\Who
Every/Was
Every/\Who

the
nun
remembered
the/e\very
child
who/\was
word1
word2

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Summary of Results: Experiment 2

Findings of Experiment 2

- Difference on word after the determiner approaches significance.
- Significant Interaction in region from POD to the following word.
Conclusions

- Quantifiers are a factor in local (first pass) ambiguity resolution.
- The parser is sensitive to "purely formal" semantic complexity as presented by quantifiers in object position.
- Semantic complexity of quantifiers is syntactically visible.
We would like to thank the Psycholinguistics class of 2005 at Pomona College, David Clausen, Stephen Conn, Jorie Koster-Moeller, Ted Gibson, and Robert Thornton for helpful comments.

Thank You!
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Thank You!