Processing adjunct control
Rapid use of structural information in reference resolution

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CLS 54
A speaker can use both (1) and (2) to mean, in part, that Mickey ate.

(1) Mickey talked to Minnie before he ate.

(2) Mickey talked to Minnie before PRO eating.

Does it matter to the timing of reference resolution if the cue is an overt pronoun or a non-finite participial verb?
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Mickey talked to Minnie [before he ate].
Mickey talked to Minnie [before he ate].
Mickey talked to Minnie [before she ate].

someone
Information that can affect pronoun interpretation:

- Morphological features of the pronoun
- Discourse prominence\(^1\)
- Coherence\(^2\)

This information can be used rapidly during online pronoun resolution.\(^3\)

\(^1\)Grosz, Weinstein, and Joshi (1995), Kehler and Rohde (2013)
\(^2\)Hobbs (1979), Kehler and Rohde (2013)
Mickey talked to Minnie [before PRO eating].
Mickey talked to Minnie [before PRO eating].

someone
Interpretation of PRO in temporal adjuncts depends on structural information.

- PRO will generally be bound by subject of next highest clause.
- No morphological features to guide interpretation.
- Discourse prominence and coherence irrelevant.

Unclear when PRO is assigned a referent, if at all.
Overt pronouns

- Pronoun is signal to anaphora
- Look for a referent in the discourse constrained by
  - morphological features of pronoun
  - discourse prominence
  - coherence

PRO

- Verb is signal to anaphora
- Look for a referent constrained by
  - syntactic structure

To what extent do these differences affect the timing of reference resolution?

- How are different kinds of information utilized in sentence processing?
In a visual-world paradigm, listeners look at the character associated with a referential expression.\(^1\)

\(^1\)Arnold et al. (2000)
### Condition | Text
--- | ---
PRO | Look there’s Mickey! Minnie was talking to him in front of a huge tree after putting on a nice new bow, and they seem to be having a good time.

pron<sub>subj</sub> | she put on a nice new bow, and they seem to be having a good time.

pron<sub>obj</sub> | he put on a nice new hat, and they seem to be having a good time.
• Used verification task to ensure participants looked at correct part of image.
• 30 sets of critical items (all TRUE)
• 20 fillers, similar to experimental items (all FALSE)
Condition | Text
--- | ---
PRO | Look there’s Mickey! Minnie was talking to him in front of a huge tree after putting on a nice new bow, and they seem to be having a good time.
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n=30

![Graph showing proportion of looks over time for both target and competitor conditions.](image-url)
- Fewer early looks to competitor for PRO ($p < 0.05$).
- Slower rate of increase in looks to target in PRO conditions ($p < 0.01$).
- But within PRO condition, looks to target appear to begin earlier.
- Looks to target diverge significantly ($p < 0.05$) from looks to competitor in PRO condition at 295 ms and in pron$_{subj}$ condition at 345 ms.
Rapid use of structural information?

Interpretation of PRO appears to be just as fast, if not faster than overt pronouns.

- Structure limits possible referents for PRO to a single character.
- Perhaps pronominal reference resolution initially involve activation of both characters, followed by filtering based on gender morphology.
  - But such models have received criticism.¹
- Cue to anaphora is longer in PRO conditions (by \( \approx 160 \) ms), so bottom-up information may not be available as quickly.

¹Kehler (2008) for example
General subject preference?

Fast processing of PRO cannot be due to simple subject preference.

- Looks in $\text{pron}_{\text{subj}}$ condition would also have initial increase relative to $\text{pron}_{\text{obj}}$. 
Participants may have been predicting an upcoming control structure.

- Did sentence context and image make control continuations likely?
- Did experimental context have a large enough proportion of control structures that participants began predicting them?
Participants may have developed strategy within experiment to look to subject character anytime they heard something other than ‘he’ or ‘she’.

- Looks to the target would not necessarily represent resolution of the control dependency.
To what extent did the item contexts lead to prediction of control structures?
Look there’s Mickey! Minnie was talking to him in front of a huge tree after _______. 
Responses were coded for whether they began with

- a non-finite verb,
- a pronoun coreferring with the main clause subject,
- a pronoun coreferring with the main clause object,
- or something else.
Experiment 1
Design
Results
Discussion
Experiment 2
Design
Results
Discussion
Experiment 3
Design
Results
Discussion
General discussion

Proportion of responses

Response type

V-ing
Pron_{subj}
Pron_{obj}
other

32/53

n=60
Examined effect of cloze probability in Experiment 2 on the results in Experiment 1.

- Higher likelihood of a control structure led to faster interpretation in PRO conditions.
- Higher cloze meant significantly fewer looks to competitor in PRO condition ($p < 0.05$).
- And marginally more looks to the target ($p = 0.09$).
Control structures were more predicted than other continuations.

- This seems to have facilitated reference resolution in PRO condition of Experiment 1.
- This facilitation was at least in part due to individual sentence/image contexts.
Did experimental context lead to faster looks in PRO condition of Experiment 1?

- Either through high proportion of control structures?
- Or through a learned strategy of assuming control for anything other than a pronoun?
Used all the materials of Experiment 1, but reduced the likelihood of control structures and of subject reference.

- Added 10 additional fillers with pron\textsubscript{obj} continuations.
- Added 30 fillers (half true, half false), with non-pronominal overt subjects in temporal adjunct.
Look there's Donald! Minnie found him outside of Daisy's house after Daisy kicked him out for being rude.
Look there’s Mickey! Minnie was talking to him in front of a huge tree after putting on a nice new bow, and they seem to be having a good time. 

She put on a nice new bow, and they seem to be having a good time.

He put on a nice new hat, and they seem to be having a good time.
• Participants slower to resolve anaphora in PRO condition.
  • Looks to target and competitor diverged in PRO condition at 410 ms, in pron\textsubscript{subj} condition at 240 ms, and in pron\textsubscript{obj} condition at 365 ms.
    • Difference in pronoun conditions may have been due to subject preference, despite extra pron\textsubscript{obj} fillers.
    • And yet PRO is still slower.

• But the cue to anaphora in PRO condition was also longer.
Effect of prediction

- Probability of control structures was reduced relative to Experiment 1.
- Cloze probability of Experiment 2 had no effect on looks in PRO condition in Experiment 3.

Participants were no longer predicting control structures (or at least not as strongly), and so interpretation was slowed.

- Individual item contexts may have induced prediction of control structures on their own
- But when the experimental context reduced the overall proportion of control structures, this information wasn’t used.
Effect of cue length

- Point of divergence in looks to subject/object in PRO condition $\approx 170$ ms later than in pron$_{subj}$ condition.
- Non-finite verbs were $\approx 160$ ms longer.
- When plotted from the offset of the critical word to account for cue length, there is no difference in processing time.
Condition | Text
---|---
PRO | Look there's Mickey! Minnie was talking to him in front of a huge tree after putting on a nice new bow, and they seem to be having a good time.
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<table>
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<tr>
<th>Target</th>
<th>Competitor</th>
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<tbody>
<tr>
<td>Proportion of looks</td>
<td>Cue</td>
</tr>
<tr>
<td></td>
<td>PRO</td>
</tr>
<tr>
<td></td>
<td>Pron\textsubscript{Subj}</td>
</tr>
<tr>
<td></td>
<td>Pron\textsubscript{Obj}</td>
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![Graph showing the proportion of looks over time for different conditions.](image-url)
Listeners are able to use structural information in anaphora resolution just as quickly as they use morphological information from a pronoun, once the relevant bottom-up input is received.
Prediction in anaphora resolution

- The role in reference resolution of predictions about coherence relations and about what referents will be mentioned next is well known.\(^1\)
- Structural predictions can also affect reference resolution.

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\(^1\)Kehler, Kertz, Rohde, and Elman (2008), Kehler and Rohde (2013), Caramazza, Yeni-Komshian, Zurif, and Carbone (1973), Hobbs (1979)
No “most-recent filler” effect

- Previous research suggested PRO is initially resolved to most recent potential filler (the object), even in subject-control adjuncts.\(^1\)
- We found no evidence that the object was considered as an antecedent to PRO before the subject was (or at all).

\(^1\)Betancort, Carreiras, and Acuña-Fariña (2006)
Usefulness of measure

- Some of the previous research on adjunct control left open the possibility that PRO was not actually being interpreted.\(^1\)
- Visual-world eyetracking demonstrates that PRO is resolved quickly during incremental sentence processing, at least in some contexts.

\(^1\)McCourt, Green, Lau, and Williams (2015) for example
Thanks!

Mike McCourt

Ellen Lau

Alexander Williams

#1449815


Non-subject control of temporal adjuncts

PRO’s referent in adjunct control is not always strictly based on structure.\(^1\)

(3) The month-old pizza\(_1\) tasted fine [after PRO\(_1\) being reheated].
(4) The month-old pizza tasted fine [after PRO being starved for a week].

How do structural biases affect interpretation when structure does not strictly determine PRO’s referent?

\(^1\)Landau (2017), Green (2018)
Effect of focus on eyetracking results

PRO condition only

Experiment 1

Experiment 2
Effect of cloze on eyetracking results

PRO condition only

Experiment 1

Experiment 2
Effect of order on eyetracking results

PRO condition only

<table>
<thead>
<tr>
<th>Order in exp.</th>
<th>early</th>
<th>late</th>
</tr>
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<tbody>
<tr>
<td>Target</td>
<td></td>
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<td>Competitor</td>
<td></td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>Time from onset of critical word</th>
<th>Proportion of looks</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 500 750 1000</td>
<td></td>
</tr>
<tr>
<td>0.00 0.25 0.50 0.75 1.00</td>
<td></td>
</tr>
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Experiment 1

<table>
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<td>0.00 0.25 0.50 0.75 1.00</td>
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Experiment 2