The time-course of anaphoric processing and syntactic reconstruction

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Goals of the study

1. To investigate whether grammar guides the process of antecedent search for anaphora in a more complicated construction

2. To resolve a puzzle raised by research on children’s interpretation of reflexives embedded in a wh-phrase
Anaphoric dependencies in language comprehension

- Anaphoric expressions in natural language
  - John believes *he* is a genius
  - John believes *himself* to be a genius
Anaphoric dependencies in language comprehension

- Anaphoric expressions in natural language
  - John believes *he* is a genius
  - John believes *himself* to be a genius

- Antecedent search in anaphoric processing
  - Mary forgot the keys when *she* left
Anaphoric dependencies in language comprehension

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  - John believes *he* is a genius
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- Antecedent search in anaphoric processing
  - Mary forgot the keys when *she* left [backward search]
Anaphoric dependencies in language comprehension

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  - John believes *he* is a genius
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- Antecedent search in anaphoric processing
  - Mary forgot the keys when *she* left [backward search]

  - When *she* left, Mary forgot the keys.
Anaphoric dependencies in language comprehension

- Anaphoric expressions in natural language
  - John believes *he* is a genius
  - John believes *himself* to be a genius

- Antecedent search in anaphoric processing
  - Mary forgot the keys when *she* left [backward search]
  - When *she* left, Mary forgot the keys. [forward search]
1. Background and motivations
   - Restricting backward and forward search: syntactic reconstruction
   - Reflexive resolution in children: A missing reading

2. Restricting the backward search (Exp 1a, 1b)

3. Restricting the forward search (Exp 2)

4. Discussion
Structural constraints on anaphora resolution

- Reflexives in English
  - *Mary* believes [that *Bill* kicked *himself*]

Reflexives must be bound in a local domain (i.e., within the same clause) (Chomsky, 1981)
Structural constraints on anaphora resolution

- Reflexives in English
  - *Mary* believes [that *Bill* kicked *himself*]

Reflexives must be bound in a local domain (i.e., within the same clause) (Chomsky, 1981)
Structural constraints on anaphora resolution

- Reflexives in English
  - Mary believes [that Bill kicked himself] 😊
  - Bill believes [that Mary kicked himself]

Reflexives must be bound in a local domain (i.e., within the same clause) (Chomsky, 1981)
Structural constraints on anaphora resolution

- Reflexives in English
  - *Mary* believes [that *Bill* kicked *himself*] 😊
  - *Bill* believes [that *Mary* kicked *himself*] 😞

Reflexives must be bound in a local domain (i.e., within the same clause) (Chomsky, 1981)
Structural constraints on anaphora resolution

- Sturt 2003

- Structural constraints guide backward search for antecedents

reminded [that the surgeon had pricked]

No GMME

Inaccessible

No Interference

accessible

He

She

herself

himself

GMME

Forward antecedent searches and prediction

- Forward search for antecedent:
  (Kazanina et al. 2007, Van Gompel & Liversedge 2003)

When she …
Forward antecedent searches and prediction

- Forward search for antecedent:
  (Kazanina et al. 2007, Van Gompel & Liversedge 2003)

When she was fed up, …
Forward antecedent searches and prediction

- Forward search for antecedent:
  (Kazanina et al. 2007, Van Gompel & Liversedge 2003)

When she was fed up, ...

Predictive parser:
Gibson 1998, Kimball 1973, Konieczny 2000,
Lau et al 2006, Levy 2006
Forward antecedent searches and prediction

- Forward search for antecedent:
  (Kazanina et al. 2007, Van Gompel & Liversedge 2003)

When she was fed up, the girl ...
Forward antecedent searches and prediction

- Forward search for antecedent:
  (Kazanina et al. 2007, Van Gompel & Liversedge 2003)

When she was fed up, the girl ...

GMM!

the boy ...

☺
Forward antecedent searches and prediction

- Kazanina et al 2007

When she … Jessica / Russell…

Structurally accessible

She … Jessica / Russell…

Structurally inaccessible

Grammatical constraints guide forward search
Interaction of wh-movement and anaphoric processing

- The studies so far investigated cases where only one direction needs to be searched
Interaction of wh-movement and anaphoric processing

- The studies so far investigated cases where only one direction needs to be searched.

- Much more complicated situation: Both directions need to be searched in sentences that involve syntactic reconstruction.
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors in English

\[ \text{John knew [}_S \text{ Bill saw a picture of himself.}] \]
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors and *argument reconstruction*

\[ \text{John knew } [\text{Bill saw } \text{a picture of himself}.] \]
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors and argument reconstruction

John knew [\textbf{Bill} saw \textbf{which} picture of \textbf{himself}.]
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors and *argument reconstruction*

\[ \text{John knew } [\text{S } \text{Bill saw which picture of himself}.] \]
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors and argument reconstruction

John knew which picture of himself [s Bill saw ___]
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors and argument reconstruction

John knew which picture of himself [\_Bill saw ___]
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors and *argument reconstruction*

*John* knew *which* picture of *himself* \([_{_S}Bill\ saw \_]\)
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors and argument reconstruction

*John knew which picture of *himself*  [\textsc{S}Bill saw ___]*
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors and *argument reconstruction*

\[\text{John knew which picture of } \underline{\text{himself}} \ [\underline{\text{Bill}} \text{ saw } \underline{\text{___}}]\]

**Surface interpretation**

**Reconstruction interpretation**
Wh-movement and reflexive: Syntactic reconstruction effects

- Anaphors and argument reconstruction

*John knew which picture of *himself [ₐ*Bill saw ___]*

1. Wh-fronting of an argument adds an interpretive possibility for the reflexive

(Barss, 1986; Heycock, 1995; Huang, 1993)
Syntactic reconstruction effects:
Argument vs. Predicate fronting

- Anaphors and *predicate reconstruction*

\[
\text{John knew } [_{S}\text{Bill was very proud of } \text{himself}.]
\]
Syntactic reconstruction effects:
Argument vs. Predicate fronting

- Anaphors and *predicate reconstruction*

  \[ \underline{John} \text{ knew } [ \underline{SBill} \text{ was } \underline{how} \text{ proud of } \underline{himself}.] \]
Syntactic reconstruction effects:
Argument vs. Predicate fronting

- Anaphors and *predicate reconstruction*

\[
\begin{align*}
\text{John} & \text{ knew how proud of himself } \text{[S Bill was ___]}
\end{align*}
\]

Same wh-movement…
Syntactic reconstruction effects:

- Anaphors and *predicate reconstruction*

\[ \text{John knew how proud of } \underline{\text{himself}} \ [\underline{s}\text{Bill was } \underline{\text{___}}] \]

2. Wh-fronting of a predicate adds NO interpretive possibility for the reflexive

(Barss, 1986; Heycock, 1995; Huang, 1993)
Syntactic reconstruction effects: Argument vs. Predicate contrast

**Argument**

*John* knew *which* picture of *himself* [*Bill* saw ___]

**Predicate**

*John* knew *how* proud of *himself* [*Bill* was ___]
Off-line acceptability (7-point scale)

Argument

John knew which picture of himself [Bill saw ___]

<table>
<thead>
<tr>
<th>Surface Interpretation</th>
<th>Reconstruction Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.69 / 7</td>
<td>5.67 / 7</td>
</tr>
</tbody>
</table>

Predicate

John knew how proud of himself [Bill was ___]

<table>
<thead>
<tr>
<th>Reconstruction Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.31 / 7</td>
</tr>
<tr>
<td>5.39 / 7</td>
</tr>
</tbody>
</table>
Time-course of reflexive resolution

**Argument**

*John* knew *which* picture of *himself* [*Bill* saw ___]

**Predicate**

*John* knew *how* proud of *himself* [*Bill* was ___]
Time-course of reflexive resolution
Argument fronting

**Argument**

\[ \text{John} \text{ knew which picture of } \text{himself [Bill saw ___] } \]

**Predicate**

\[ \text{John} \text{ knew how proud of } \text{himself [Bill was ___] } \]
Time-course of reflexive resolution
Argument fronting

Argument

John knew which picture of himself [Bill saw ___]

Predicate

John knew how proud of himself [Bill was ___]

(surface interpretation

INITIAL interpretation

(Immediate forward anaphor resolution: Nicol & Swinney, 1989; Sturt 2003)
Time-course of reflexive resolution
Argument fronting

**Argument**

*John* knew *which* picture of *himself* [*Bill* saw ___]

**Predicate**

*John* knew *how* proud of *himself* [*Bill* was ___]
Time-course of reflexive resolution
Argument fronting

Argument

*John* knew *which* picture of *himself* [*Bill* saw ___]

Predicate

*John* knew *how* proud of *himself* [*Bill* was ___]
Time-course of reflexive resolution
Predicate fronting

Argument

John knew which picture of himself [Bill saw ___]

Predicate

John knew how proud of himself [Bill was ___]
Time-course of reflexive resolution: Predicate fronting

Argument

John knew which picture of himself [Bill saw ___]

Predicate

John knew how proud of himself [Bill was ___]

Surface interpretation should be blocked
Time-course of reflexive resolution: Predicate fronting

Argument

John knew which picture of himself [Bill saw ___]

Predicate

John knew how proud of himself [Bill was ___]
Time-course of reflexive resolution: Predicate fronting

**Argument**

\[ \text{John knew which picture of himself [Bill saw \_]} \]

**Predicate**

\[ \text{John knew how proud of himself [Bill was \_]} \]

Surface interpretation:
- Initial interpretation
- Second interpretation

Reconstruction interpretation:
- Initial interpretation
- Second interpretation
Time-course of reflexive resolution: Predicate fronting

Argument

John knew which picture of himself [Bill saw ___]

Predicate

John knew how proud of himself [Bill was ___]

Does the parser actually behave this way?
Children’s knowledge of argument vs. predicate asymmetry in syntactic reconstruction effects
Leddon & Lidz 2005: Children’s reconstruction effects

- Children’s knowledge of argument vs. predicate asymmetry in syntactic reconstruction effects

Truth Value Judgment Task (offline)

**Argument**

Miss Cruella figured out which picture of *herself* Janie put up.

**Predicate**

Mr. Monkey figured out how proud of *himself* Andy was.
Children’s behavior: Argument vs. Predicate contrast

Argument

John knew which picture of himself [Bill saw ___]

Predicate

John knew how proud of himself [Bill was ___]

No!
Children’s behavior: Argument vs. Predicate contrast

**Argument**

*John* knew *which* picture of *himself* [*Bill* saw ___]

**Predicate**

*John* knew *how* proud of *himself* [*Bill* was ___]
Children’s behavior: Argument vs. Predicate contrast

**Argument**

*John* knew *which* picture of *himself* [*Bill* saw ___]

- **YES!**
- surface interpretation
- INITIAL interpretation
- reconstruction interpretation

**Predicate**

*John* knew *how* proud of *himself* [*Bill* was ___]

- **No!**
- reconstruction interpretation
- INITIAL interpretation
Children’s behavior: Argument vs. Predicate contrast

**Argument**

John knew which picture of himself [Bill saw ___]

*YES!*

**Predicate**

John knew how proud of himself [Bill was ___]

*NO WAY!*

*YES!*

*No!*

**Children’s behavior:** Argument vs. Predicate contrast

- **INITIAL interpretation**
- **SECOND interpretation**
- **surface interpretation**
- **reconstruction interpretation**

**YES!**

**No!**
Children’s behavior: Argument vs. Predicate contrast

**Argument**

*John* knew which picture of *himself* [*Bill* saw ___]

- Surface interpretation
- Initial interpretation

**Predicate**

*John* knew how proud of *himself* [*Bill* was ___]

- Reconstruction interpretation
- Initial interpretation

Reanalysis is hard (Trueswell et al 1999)

NO WAY!

YES!

Reanalysis is hard (Trueswell et al 1999)

NO!

YES!
Children’s behavior: Argument vs. Predicate contrast

**Argument**

John knew which picture of himself

--

Adult’s **INITIAL** = Child’s **ONLY**

**Predicate**

John knew how proud of himself

--

** Bracket**

**Bill saw ___**

**Bill was ___**

**surface interpretation**

**reconstruction interpretation**

**YES!**

**YES!**

**NO WAY!**

**INITIAL interpretation**

**SECOND interpretation**

**Adult’s** **INITIAL**

**Child’s** **ONLY**

Adult’s = Child’s

ONLY

**CHILDREN'S behavior:** Argument vs. Predicate contrast
Summary so far

- Adult’s *initial* interpretation = Child’s *only* interpretation

- Child’s divergence is due to a difference in the parser, not in grammar (Leddon & Lidz 2005)
Summary so far

Adult’s initial interpretation

= Child’s only interpretation

- Child’s divergence is due to a difference in the parser, not in grammar (Leddon & Lidz 2005)
- Is the hypothesized time-course plausible?
Argument

John knew which picture of himself [Bill saw ___]

Predicate

John knew how proud of himself [Bill was ___]
Argument

John knew which picture of himself

Predicate

John knew how proud of himself [Bill saw ___]

Experiment 1

Surface interpretation

INITIAL interpretation

Experiment 2

reconstruction interpretation

SECOND interpretation

[Bill was ___]
Experiment 1a: Self-paced reading

- 4 conditions (Arg vs. Pred x Match vs. Mismatch)
- 24 targets (4 lists), 96 fillers
- 24 participants
- word-by-word, moving window
Experiment 1a: Design

**Argument**

Patrick knew which picture of himself ...

Rachel

**Predicate**

Patrick knew how proud of himself ...

Rachel
Experiment 1a: Design

**Argument**

- Patrick knew **which** picture of **himself** ...
- Rachel

**Predicate**

- Patrick knew **how** proud of **himself** ...
- Rachel

Surface interpretation

INITIAL interpretation

GMM!
Experiment 1a: Design

**Argument**

Patrick knew **which** picture of **himself** ...

Rachel

**Predicate**

Patrick knew **how** proud of **himself** ...

Rachel

No GMME
Patrick / Rachel knew which rumor about himself the popular highschool quarterback was likely to spread…
**Patrick / Rachel** knew how ashamed of **himself** the popular highschool quarterback was likely to feel …
Experiment 1a: Summary

Argument

Patrick knew which picture of himself ...

Rachel

Predicate

Patrick knew how proud of himself ...

Rachel

No GMME

GMM!
Experiment 1a: Summary

**Argument**

Patrick knew *which* picture of *himself* …

Rachel

**Predicate**

Patrick knew *how* proud of *himself* …

Rachel

*Surface interpretation*

*INITIAL interpretation*

GMM! Confirmed!

No GMME
Experiment 1a: Summary

**Argument**

Patrick knew *which* picture of *himsel*f ...

Rachel

**Predicate**

Patrick knew *how* proud of *himself* ...

Rachel

- **GMM!** Confirmed!
- **No GMME** Not confirmed...
Immediate resolution in predicate condition?

- Is the antecedent search not fully constrained by grammar?
Immediate resolution in predicate condition?

- Is the antecedent search not fully constrained by grammar?
- However, the surface interpretation is available if there is a pronoun in the embedded clause.
Immediate resolution in predicate condition?

- Is the antecedent search not fully constrained by grammar?
- However, the surface interpretation is available if there is a pronoun in the embedded clause

John₁ forgot how proud of himself₁ he₁ was…
Immediate resolution in predicate condition?

- Is the antecedent search not fully constrained by grammar?
- However, the surface interpretation is available if there is a pronoun in the embedded clause

\[ \text{John}_1 \text{ forgot how proud of himself}_1 \text{ he}_1 \text{ was…} \]
Immediate resolution in predicate condition?

- Is the antecedent search not fully constrained by grammar?
- However, the surface interpretation is available if there is a pronoun in the embedded clause

John$_1$ forgot how proud of himself$_1$ he$_1$ was…
Immediate resolution in predicate condition?

- Is the antecedent search not fully constrained by grammar?
- However, the surface interpretation is available if there is a pronoun in the embedded clause

\[ \text{John}_1 \text{ forgot how proud of } \text{himself}_1 \text{ he}_1 \text{ was…} \]
Immediate resolution in predicate condition?

- Is the antecedent search not fully constrained by grammar?
- However, the surface interpretation is available if there is a pronoun in the embedded clause.

John$_1$ forgot how proud of himself$_1$ he$_1$ was…

Pronoun prediction?
Experiment 1b: Sentence completion

- Tests if pronouns are predicted in predicate match condition
- Sentence completion results often correlate with predictive behavior in on-line comprehension
- \( N = 16 \)
Experiment 1b: Sentence completion

argument, match

   Josh knew which picture of himself…

argument, mismatch

   Jeniffer knew which picture of himself…

predicate, match

   Josh knew how pleased with himself…

predicate, mismatch

   Jeniffer knew how pleased with himself…
Experiment 1b: Sentence completion

argument, match
 Josh knew which picture of himself…

argument, mismatch
 Jeniffer knew which picture of himself…

predicate, match
 Josh knew how pleased with himself… he?

predicate, mismatch
 Jeniffer knew how pleased with himself…
Experiment 1b: Sentence completion

pronoun production

Arg-Match | Arg-MM | Pred-Match | Pred-MM
Experiment 1a & 1b: Summary

Argument
Patrick knew which picture of himself …
Rachel

 Predicate
Patrick knew how proud of himself …
Rachel

[Diagram with entities and connections]

GMM!
Confirmed!

No GMME
Not confirmed…
Experiment 1a & 1b: Summary

**Argument**

Patrick knew *which* picture of *himself* ...

Rachel

**Predicate**

Patrick knew *how* proud of *himself* ...

Rachel

---

**GMM!**

Confirmed!

No GMME

Not confirmed...

Pronoun prediction
**Experiment 2**

**Argument**

*John* knew *which* picture of *himself* [*Bill* saw ___]

**Predicate**

*John* knew *how* proud of *himself* [*Bill* was ___]
Experiment 2: Self-paced reading

- 4 conditions (Arg vs. Pred x Match vs. Mismatch)
- 24 targets (4 lists), 96 fillers
- 44 participants
- word-by-word, moving window
Experiment 2 design

Argument

Patrick knew which picture of herself [… alcoholic …]
Rachel

Predicate

Patrick knew how proud of herself [… alcoholic …]
Rachel

surface interpretation
reconstruction interpretation
INITIAL interpretation
SECOND interpretation

Patrick himself
Rachel herself
Experiment 2 design

Argument
Patrick knew which picture of himself
Rachel himself

Predicate
Patrick knew how proud of herself
Rachel himself

No GMME
[... alcoholic ...]

Surface interpretation
INITIAL interpretation
SECOND interpretation

reconstruction interpretation

INITIAL interpretation

reconstruction interpretation
Experiment 2 design

Argument

Patrick knew which picture of himself [... alcoholic ...]
Rachel knew how proud of herself [... alcoholic ...]

Predicate

Patrick knew how proud of himself [... alcoholic ...]
Rachel knew how proud of herself [... alcoholic ...]
Exp 2 results: argument conditions

Patrick / Rachel found out which story about himself / herself the alcoholic had spread …
Patrick / Rachel found out which story about himself / herself the alcoholic had spread …
Predicate condition results: Linear Mixed-Effects Model

Factor out predicted amount of noise (e.g., spill-over effect) based on non-experimental manipulation.
Exp 2 results: Arg vs Pred

- **Arg-Match**
- **Arg-Mismatch**

- **Pred-Match**
- **Pred-Mismatch**

*Note: Representation of data points and error bars for comparison between arguments and predictions in Experiment 2.
Experiment 2 summary

**Argument**

Patrick knew which picture of Rachel himself

No GMME

[k... alcoholic ...]

**Predicate**

Patrick knew how proud of Rachel himself

GMME!

[k... alcoholic ...]

reconstruction interpretation

INITIAL interpretation

reconstruction interpretation

INITIAL interpretation
Experiment 2 summary

Argument

Patrick knew which picture of
Rachel

himself herself
[... alcoholic ...]

reconstruction interpretation

INITIAL interpretation

Predicate

Patrick knew how proud of
Rachel

himself herself
[... alcoholic ...]

reconstruction interpretation

INITIAL interpretation

Confirmed!

No GMME
Experiment 2 summary

Argument

Patrick
Rachel

knew which picture of

himself
herself

[... alcoholic ...]

Predicate

Patrick
Rachel

knew how proud of

himself
herself

[... alcoholic ...]

No GMME

Confirmed!

GMME!

Confirmed!

Surface interpretation

INITIAL interpretation

Reconstruction interpretation

SECOND interpretation

No GMME

Confirmed!
Discussion: Argument fronting

**Argument**

John knew **which** picture of **himself** [Bill saw ___]

**Predicate**

John knew **how** proud of **himself** [Bill was ___]
Discussion: Argument fronting

**Argument**

*John* knew *which* picture of *himself*[

*Bills* saw ___]

**Predicate**

*John* knew *how* proud of *himself*[

*Bills* was ___]

---

**Surface interpretation**

**Reconstruction interpretation**

**INITIAL interpretation**

**SECOND interpretation**
Discussion: Argument fronting

**Argument**

*John* knew *which* picture of *himself [Bill saw ___]*

**Predicate**

*John* knew *how* proud of *himself [Bill was ___]*
Discussion: Argument fronting

Argument

John knew which picture of himself [Bill saw ___]

Predicate

John knew how proud of himself [Bill was ___]
Discussion: Predicate fronting

**Argument**

*John* knew *which* picture of *himself* *[Bill]* saw ___

**Predicate**

*John* knew *how* proud of *himself* *[Bill]* was ___

- **surface interpretation**
- **reconstruction interpretation**
- **INITIAL interpretation**
- **SECOND interpretation**
Discussion: Predicate fronting

Argument

John knew which picture of himself [Bill saw ___]

Predicate

John knew how proud of himself [Bill was ___]
Discussion: Predicate fronting

**Argument**

*John* knew *which* picture of *himself* [*Bill* saw ___]

**Predicate**

*John* knew *how* proud of *himself* [*Bill* was ___]
Discussion: Predicate fronting

**Argument**

John knew which picture of himself [Bill saw ___]

**Predicate**

John knew how proud of himself [Bill was ___]
Discussion: Predicate fronting

**Argument**

John knew which picture of himself [Bill saw ___]

**Predicate**

John knew how proud of himself [Bill was ___]

[Image of a baby]

Pronoun prediction

reconstruction interpretation

INITIAL interpretation

reconstruction interpretation

SECOND interpretation
Thank you

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