Immature Filler-Gap Dependency Processing in 5- to 7-Year-Olds

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Parser development

• Majority of work in psycholinguistics examines adult processing

• Discovering immature parsing mechanisms could allow us to…
  • Reveal subtle details of the parsing mechanisms not detected in adult processing studies
  • Shed light on models of adult parsing
  
  (e.g., Snedeker & Trueswell 2004; Trueswell et al. 1999)

Today: Present novel findings that children's syntactic predictions in filler-gap dependency processing are immature
Incremental parsing in children

- Both 5-year-olds & adults incrementally parse sentences
- PP-attachment ambiguity (Trueswell et al. 1999)

(1) Put the frog **on the napkin**…

(see also e.g., Borovsky et al. 2012; Lew-Williams & Fernald 2007; Mani & Huettig 2012; Nation et al. 2003)
Immature syntactic predictions?

- **PP attachment ambiguity** – selection among 2 available structures for bottom-up input

  - Syntactic prediction – building structure without bottom-up evidence for that structure

    The book that the author… wrote __ … wrote the review about __ … said that the reviewer hated __ …
Immature syntactic predictions?

• Predictions are fundamental to many cognitive processes
  • Domains outside of language – e.g., vision
    (e.g., Murray et al. 2002; Ullman 1984; Yuille & Kersten 2006)

• Syntactic predictions a crucial component in sentence processing
  (e.g., Resnick 1992; Staub & Clifton 2006; Yoshida et al. 2013)
  • Little work has examined children’s syntactic predictions (or lack thereof)
Adult filler-gap dependency processing

• **Active gap filling** (e.g., Frazier 1987, Traxler & Pickering 1996)
  • Adult parser makes a direct object gap prediction upon processing the filler
  • Potentially ‘reckless’ strategy – interpretation before bottom-up evidence for gap in argument structure
    • Prediction can be incorrect → leads to revision

(1) **What** did Julie paint the door with **__** ?
(2) The zebra that the hippo had kissed __ on the nose ran far away.

- 4- to 6-year-olds make faster judgments when presented picture of zebra (filler) vs. hippo (subject)
- Result may not involve reactivation of filler
  - Children may treat the picture as the local direct object
    - the hippo had kissed the zebra / *the hippo
  - Filler animal = more coherent continuation of the local sentence fragment
Omaki et al. 2014

• Used answers to ambiguous bi-clausal questions (3) to examine children’s filler-gap dependency processing

(3) **Where** did Lizzie tell someone ? that she was going to catch a butterfly ?

5-year-olds’ & adults answer: telling location

• Filler is being incrementally interpreted at the first available verb
  • Converging evidence in French & Japanese (Omaki et al. 2014; Lassota et al. 2015)

• Lacked timecourse evidence → not strong evidence for active gap filling
  • Use visual world eye tracking to examine gap predictions during processing
Experiment 1: Adults & 5-year-olds

• 19 native English speaking children between 5;0 and 5;11
  • Mean age = 5;5, 8 females
• 22 native English speaking Johns Hopkins Undergraduates

• Question-after-story design
  (based on Sussman & Sedivy 2003; Omaki 2010)
  • 20 total trials (10 targets, 10 fillers)
Can you tell me...

what Emily was eating the cake with __?

if Emily was eating the cake with the fork?
Eye movement predictions

- Can you tell me…
  - what Emily was eating…
  - if Emily was eating…

(see also Omaki 2010; Sussman & Sedivy 2003)
Eye movement predictions

• Can you tell me…

  **what** Emily was *eating*…
  if Emily was *eating*…

(see also Omaki 2010; Sussman & Sedivy 2003)
Eye movement predictions

- Can you tell me…

  what Emily was eating…

  if Emily was eating…

(see also Omaki 2010; Sussman & Sedivy 2003)
Verb region: Adults

- Greater increase in fixations on the target object during *wh*-questions
Verb region: 5-year-olds

- Similar increase in fixations on the target object in both conditions
Verb region: Both age groups

- Significant interaction of age group & question type ($p < 0.001$)
- Significant pairwise comparisons – adults ($p < 0.001$); 5-year-olds ($p < 0.001$)
Evidence for structural predictions

- Verb region results = 5-year-olds’ structural predictions are immature
- NP region = Evidence children *can* make adult-like structural predictions

Can you tell me what Emily was eating the cake with __?
Greater increase in fixations on the target instrument during *wh*-questions
Greater increase in fixations on the target instrument during *wh*-questions
Significant interaction of age group & question type ($p < 0.001$)

Significant pairwise comparisons – adults ($p < 0.001$); 5-year-olds ($p < 0.001$)
Experiment 2: Older children

- Found immature active gap filling in 5-year-olds
  - Suggests that active gap filling strategy must develop

- Would older children actively complete the dependency at the direct object position?

- 35 native English speaking children between the ages of 6;0 and 8;0
  - 19 children between the ages of 6;0 and 7;0 (mean = 6;4, 12 females)
  - 16 children between the ages of 7;0 and 8;0 (mean = 7;5, 8 females)
Verb region: 6- & 7-year-olds

- No significant difference between the 6- & 7-year-olds
- Similar increase in fixations on the target object in both conditions, like 5-year-olds
• Significant interaction of age group & question type ($p < 0.001$)
• Significant pairwise comparisons – adults ($p < 0.001$); 6- & 7-year-olds ($p < 0.001$)
• No significant difference between 6- & 7-year-olds
• Greater increase in fixations on the target instrument during *wh*-questions, like 5-year-olds
• Significant interaction age group & question type ($p < 0.001$)
• Significant pairwise comparisons – adults ($p < 0.001$); 6- & 7-year-olds ($p < 0.001$)
Implications

• 5- to 7-year-olds’ fixation pattern during the verb is different from that of adults
  • Suggests they may not predict a direct object gap

• Are there other relevant factors?
  • Age in months
  • Comprehension vocabulary size
    • Measured using raw score on Peabody Picture Vocabulary Test (PPVT™-4)
      (see Borovsky et al. 2012; Mani & Huettig 2012; Nation et al. 2003)
  • Language experience
Other factors: Age & vocabulary size

- Difference scores (verb region)

  Proportion object fixations in *wh*-questions – Proportion object fixations in *yes-no* questions
Other factors: Age & vocabulary size

- Difference scores (verb region)
  Proportion object fixations in *wh*-questions – Proportion object fixations in *yes-no* questions

- No significant correlations
  - Age in months: $R^2 = 0.02, p > 0.1$
  - Vocabulary size: $(R^2 = 0.04, p > 0.1)$
Other factors: Language experience

- Children may not have been exposed to an adult-like distribution of object and PP gap questions
- Probabilistic parsing model (e.g., Levy 2008)
  - Derive probability of gap positions from input statistics
  - Predict gap position based on the most probable continuation
  - Structural predictions reflect the input

Distribution in favor of object gaps leads to object gap prediction

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<th>Object Gaps</th>
<th>Preposition Gaps</th>
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<tr>
<td></td>
<td>Overt PP</td>
<td>No PP</td>
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<tr>
<td></td>
<td>1,192</td>
<td>2,022</td>
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<td></td>
<td>33.1%</td>
<td>56.2%</td>
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</tbody>
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(Abe, Adam, Naomi, Nina, & Sarah Corpora; CHILDES)
A conservative prediction strategy?

- Active gap filling is a somewhat reckless strategy → the parser commits to an interpretation that could be incorrect
- Developing parser may be more conservative than the adult parser
- Conservative predictions lead to revision avoidance
  - Children notably struggle to revise their initial interpretations (e.g., Trueswell et al. 1999)
Conservative prediction strategy: Verb region

Can you tell me what Emily was eating…

Predict object gap!
Conservative prediction strategy: NP region

Can you tell me what Emily was eating the cake…?
Conclusion

• 5- to 7-year-olds process *wh*-questions differently than adults, especially in the verb region
  • Processing behavior not modulated by age or vocabulary size

• Children may be more conservative in their predictions than adults
  • Similar effects in adults if probability of gap positions altered?

• Language experience may be necessary for active gap filling, but it is not sufficient
  • Implications for probabilistic parsing models → Predictions based on probabilities need to be more nuanced to account for child data
  • Pilot picture book priming study
Thank you!

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  • My participants and their parents
  • Katherine Simeon
  • Will Harrison
  • Melinh Lai
  • Language Processing & Development Lab
  • Colin Wilson

Questions?
Sample question audio
Timecourse: Adults

Wh-Questions (Adults)

Subject + was (Emily was)  Verb (eating)  Object NP (the cake)  Preposition (with)

Yes-No Questions (Adults)

Subject + was (Emily was)  Verb (eating)  Object NP (the cake)  PP (with the fork)
Timecourse: 5- to 7-year-olds

**Wh-Questions (Children, all ages)**
- Subject + was (Emily was)
- Verb (eating)
- Object NP (the cake)
- Preposition (with)

**Yes-No Questions (Children, all ages)**
- Subject + was (Emily was)
- Verb (eating)
- Object NP (the cake)
- PP (with the fork)
Verb region: 6- & 7-year-olds

Fixations on Target Object (6-year-olds)

Fixations on Target Object (7-year-olds)
Direct object region: 6- & 7-year-olds

Fixations on Target Instrument
(6-year-olds)

Fixations on Target Instrument
(7-year-olds)

Proportion of Fixations

Time After Object Onset (ms)

Wh-Questions
Yes-No Questions

Wh-Questions
Yes-No Questions
Mani & Huettig 2012: Anticipatory fixations

• 2-year-olds’ make anticipatory fixations on likely object in same timecourse as adults’
  • The boy *eats* the big cake. (constraining)
  • The boy *sees* the big cake. (neutral)
Borovsky et al. 2012

• 3- to 10-year-olds’ anticipatory fixations on possible object given context in same timecourse as adults’
  • The pirate *hides* the treasure.
  • The dog *hides* the bones.
Adult distributional analysis

• 2 LDC corpora – natural speech
  • CALLHOME
  • Selections from Switchboard

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<tr>
<th></th>
<th>Object Gaps</th>
<th>Preposition Gaps</th>
<th>Total</th>
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<tbody>
<tr>
<td>Number</td>
<td>471</td>
<td>59</td>
<td>530</td>
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