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)

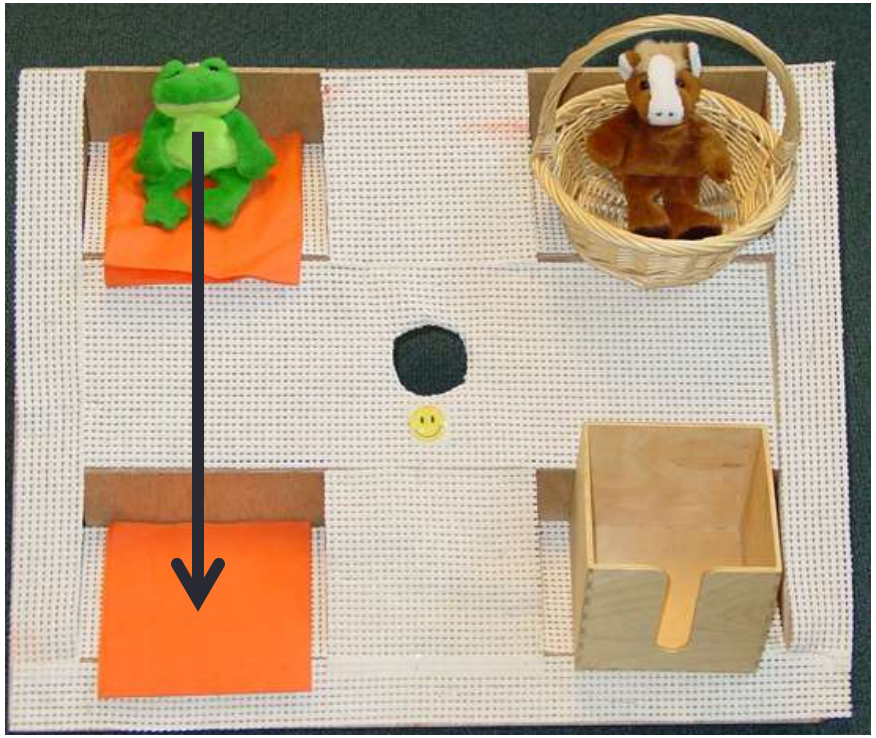
Today: Present novel findings that children's syntactic predictions in filler-gap dependency processing are immature

Incremental parsing in children

- Both 5-year-olds & adults incrementally parse sentences

- PP-attachment ambiguity (Trueswell et al. 1999)

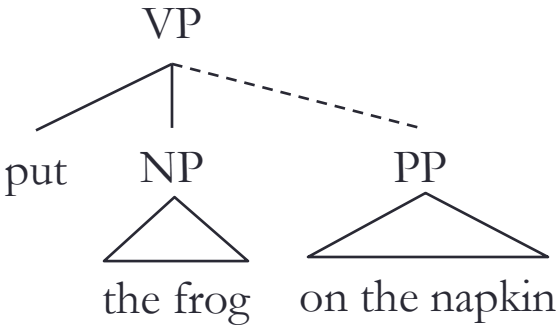
(1) Put the frog **on the napkin**…

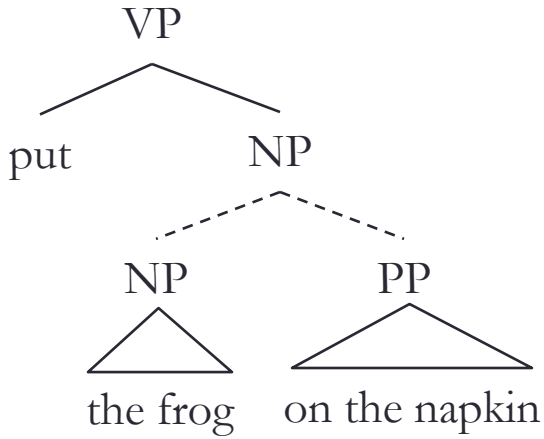


(see also e.g., Borovsky et al. 2012; Lew-Williams & Fernald 2007; Mani & Huettig 2012; Nation et al. 2003)

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

<u>The book</u> 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)

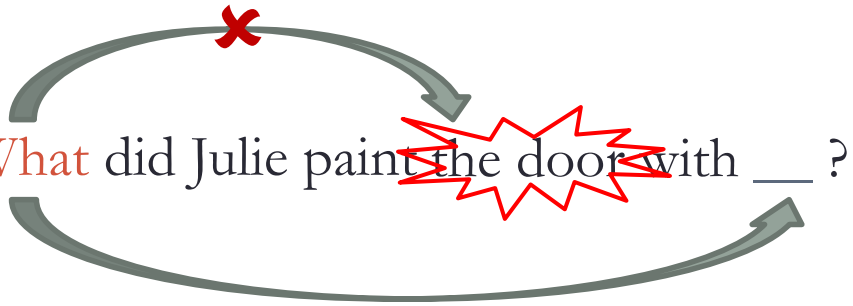
- Syntactic predictions a crucial component in sentence processing

(e.g., Resnick 1992; Staub & Clifton 2006; Yoshida et al. 2013)

  - Little work has examined children's syntactic predictions (or lack thereof)

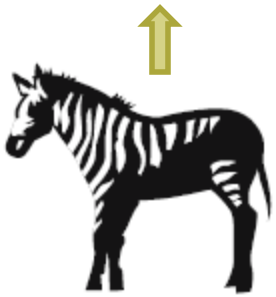
Adult filler-gap dependency processing

- 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



Love 2007

(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)

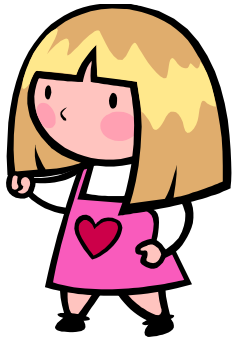
- Lacked timecourse evidence → not strong evidence for active gap filling
  - Use visual world eye tracking to examine gap predictions during processing

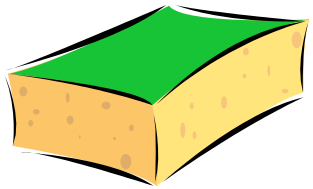
Experiment 1: Adults & 5-year-olds

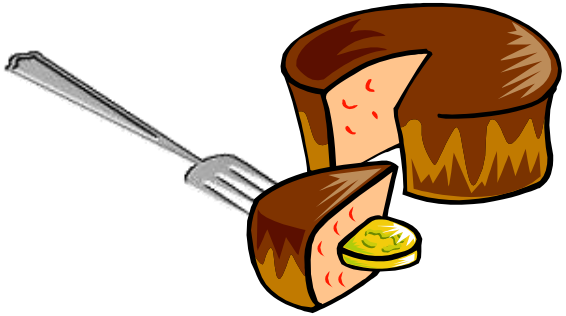
- 19 native English speaking children between 5;0 and 5;11
  - Mean age = 5;5, 8 females
- 22 native English speaking Johns Hopkins Undergraduates

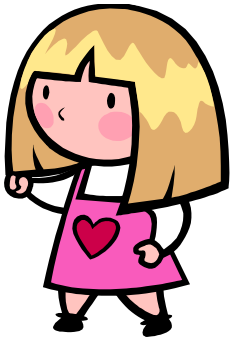
- Question-after-story design

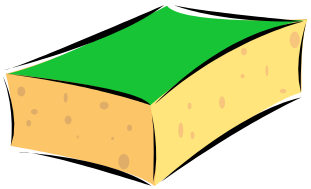
  (based on Sussman & Sedivy 2003; Omaki 2010)
  - 20 total trials (10 targets, 10 fillers)

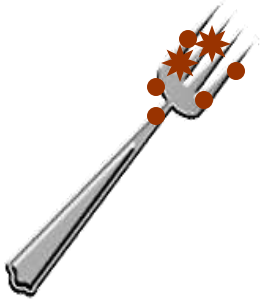


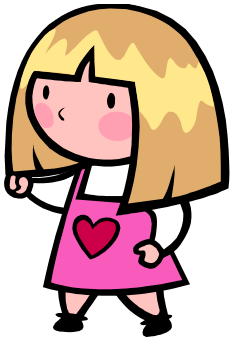


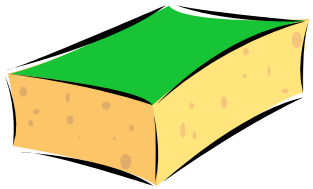


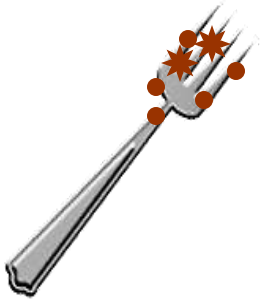


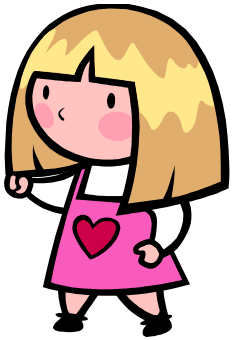


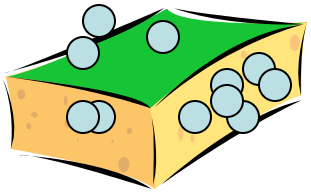


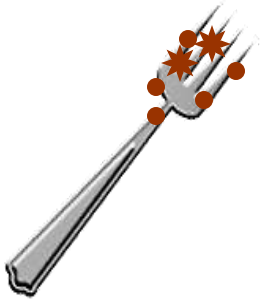


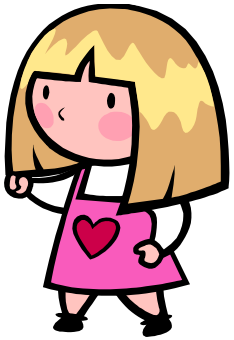


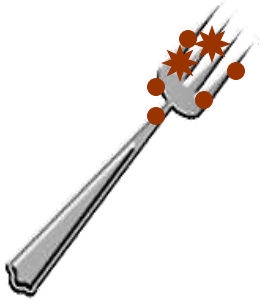








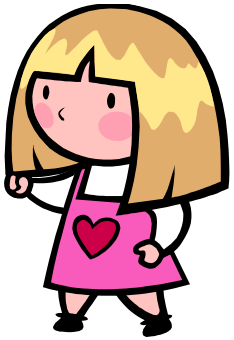


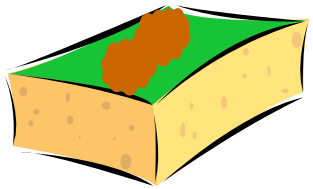


Can you tell me…

what Emily was eating the cake with __?

if Emily was eating the cake with the fork?



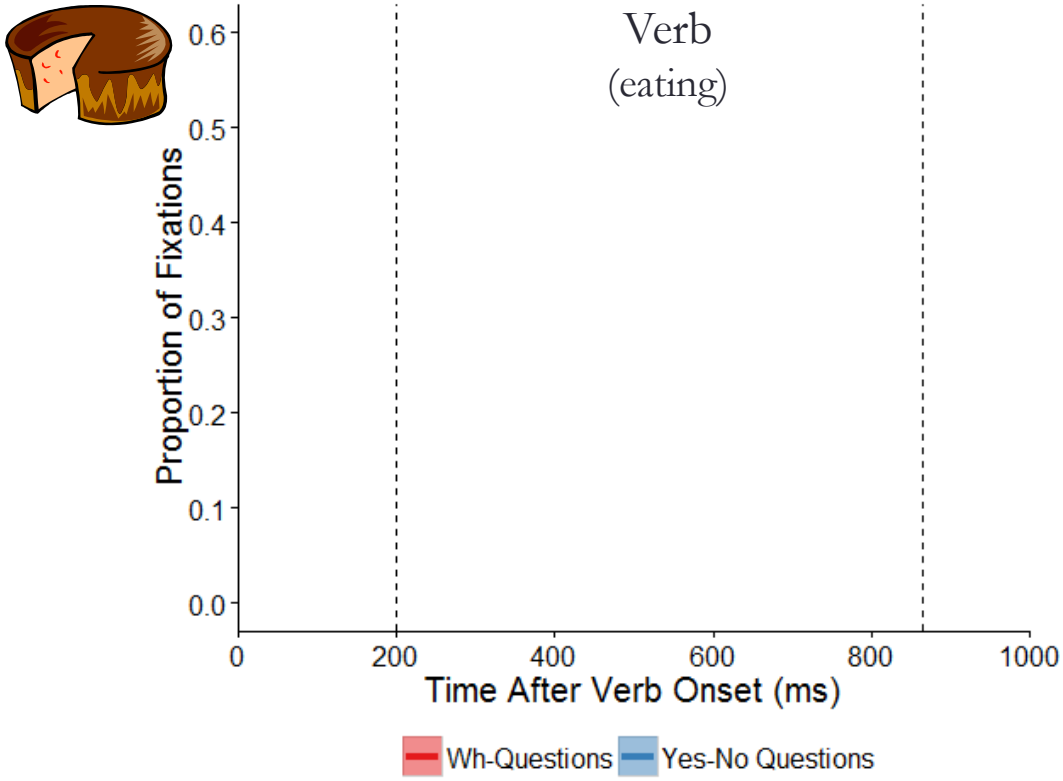


Eye movement predictions

- Can you tell me…

  what Emily was **eating**…

  if Emily was **eating**…



(see also Omaki 2010; Sussman & Sedivy 2003)

Eye movement predictions

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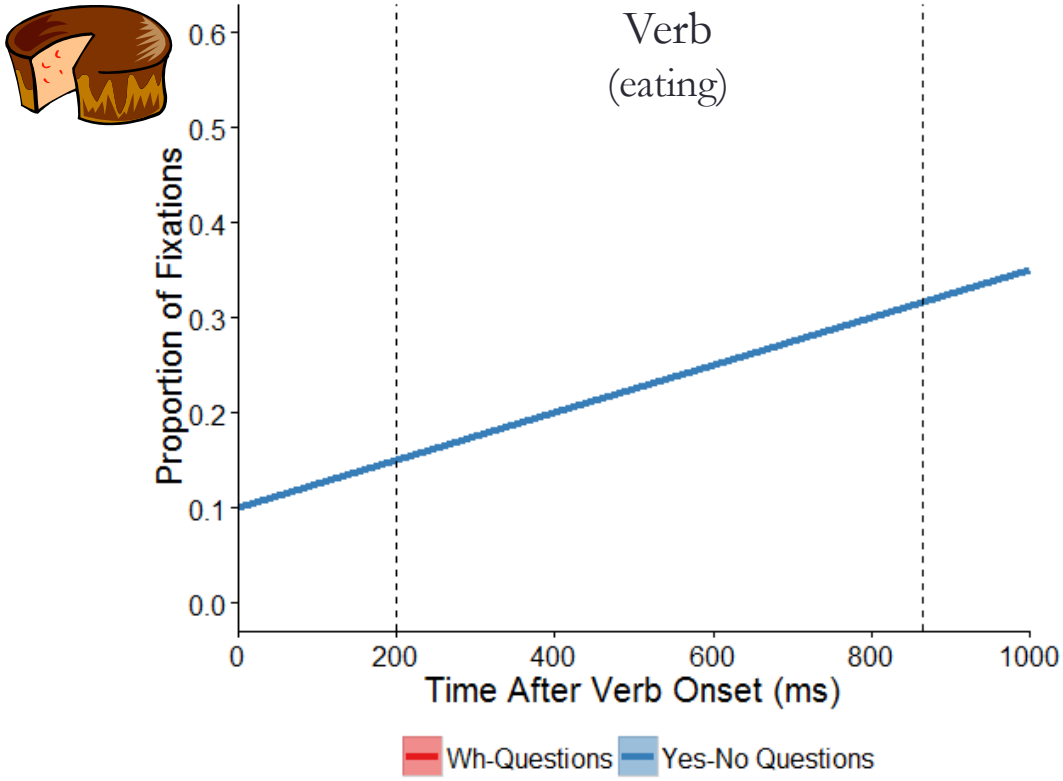


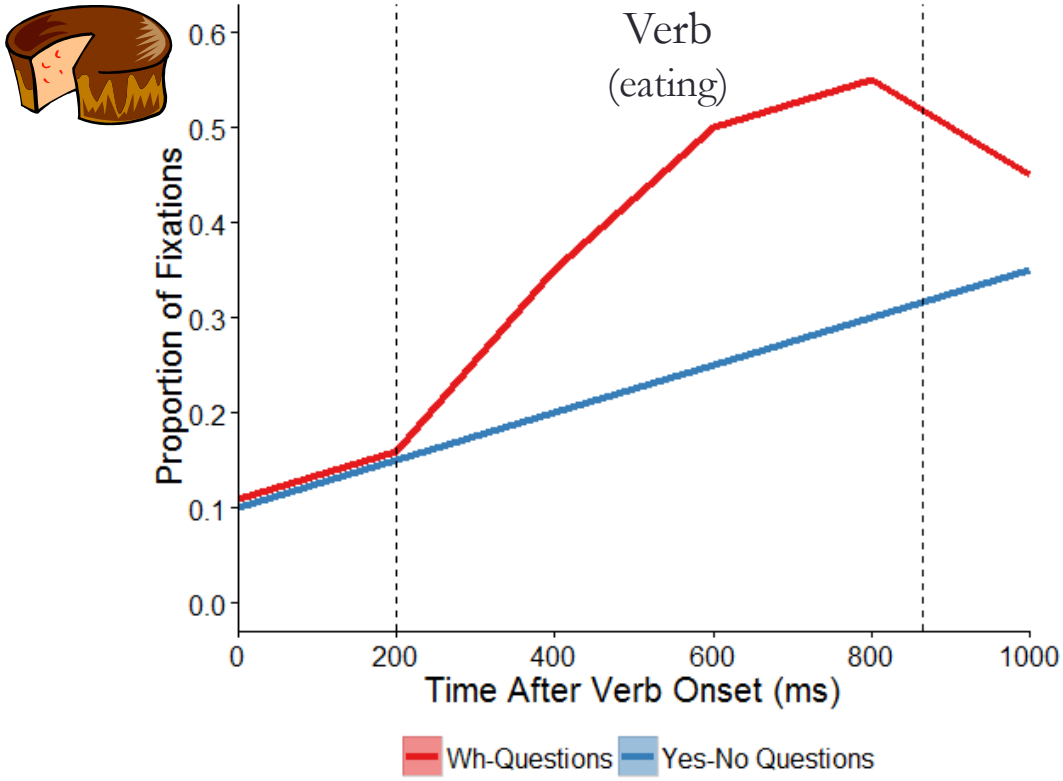
(see also Omaki 2010; Sussman & Sedivy 2003)

Eye movement predictions

- Can you tell me…

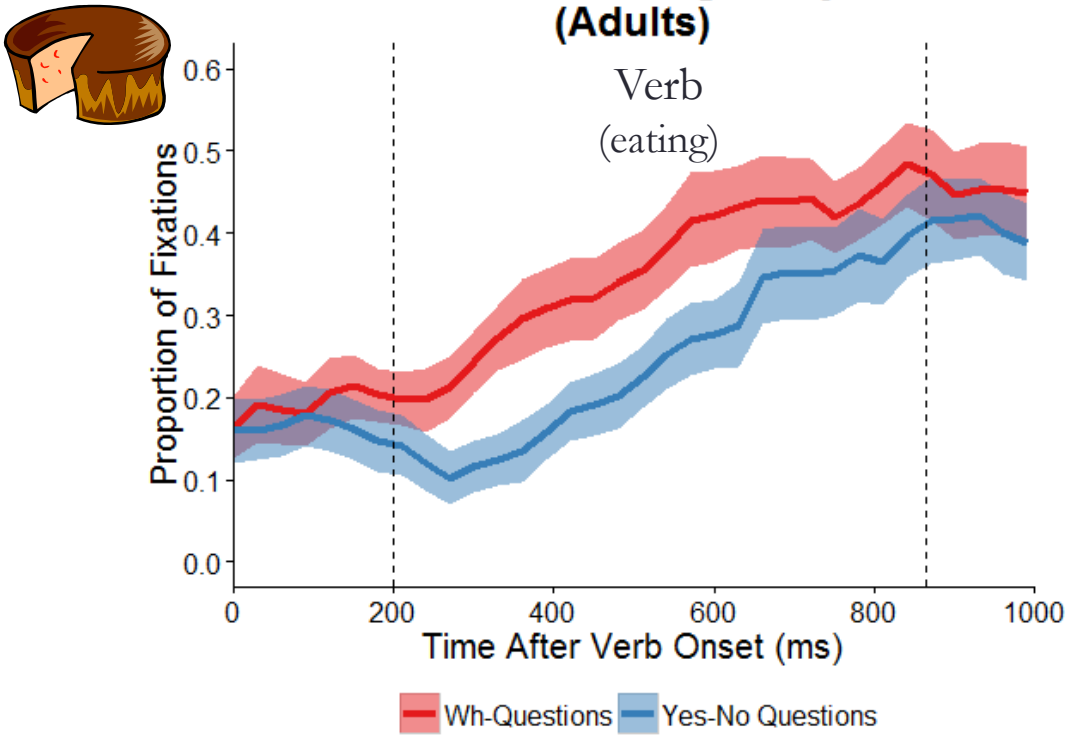
  what Emily was **eating**…

  if Emily was **eating**…



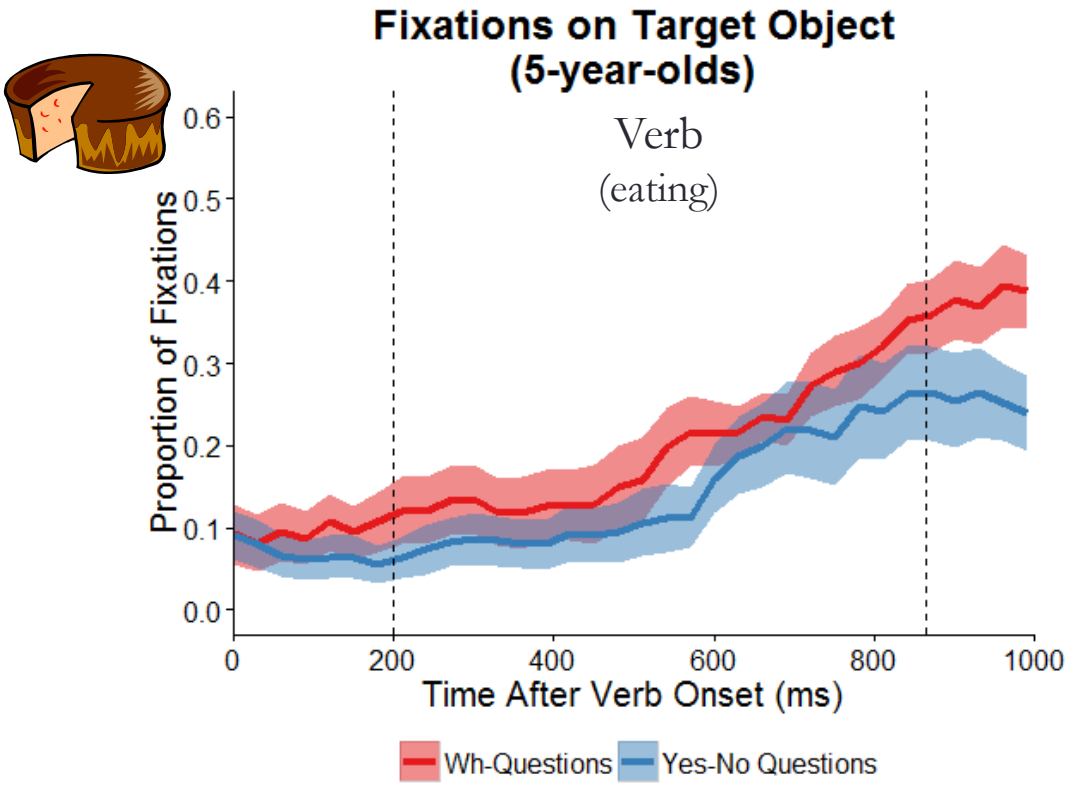
(see also Omaki 2010; Sussman & Sedivy 2003)

Verb region: Adults



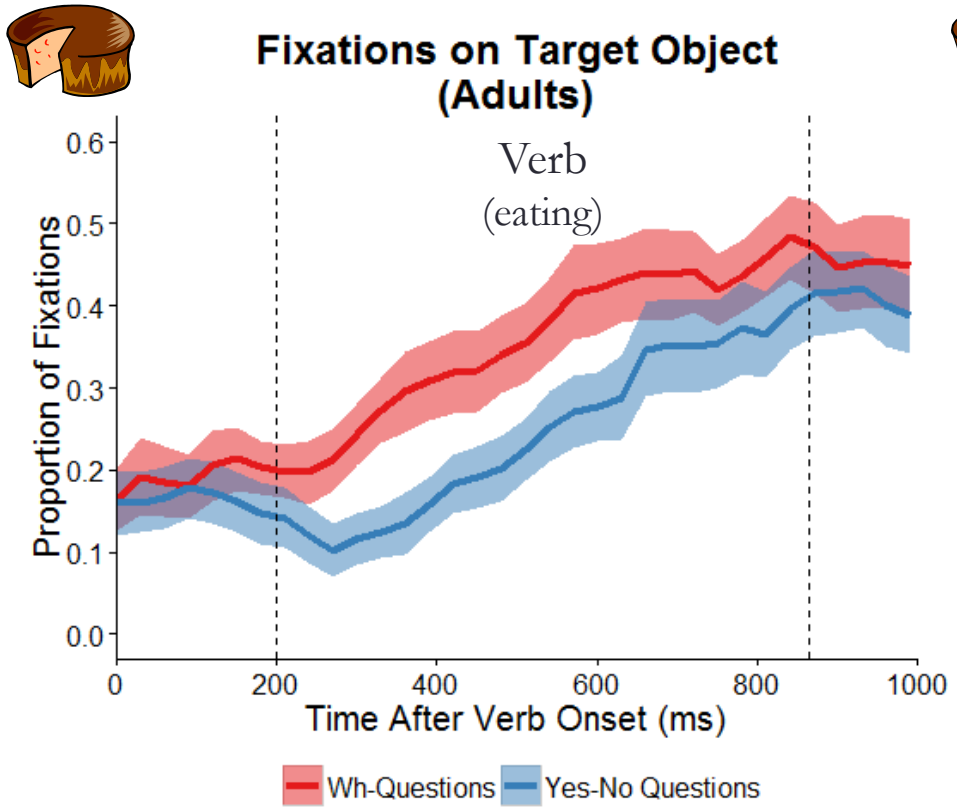
- Greater increase in fixations on the target object during ***wh*-questions**

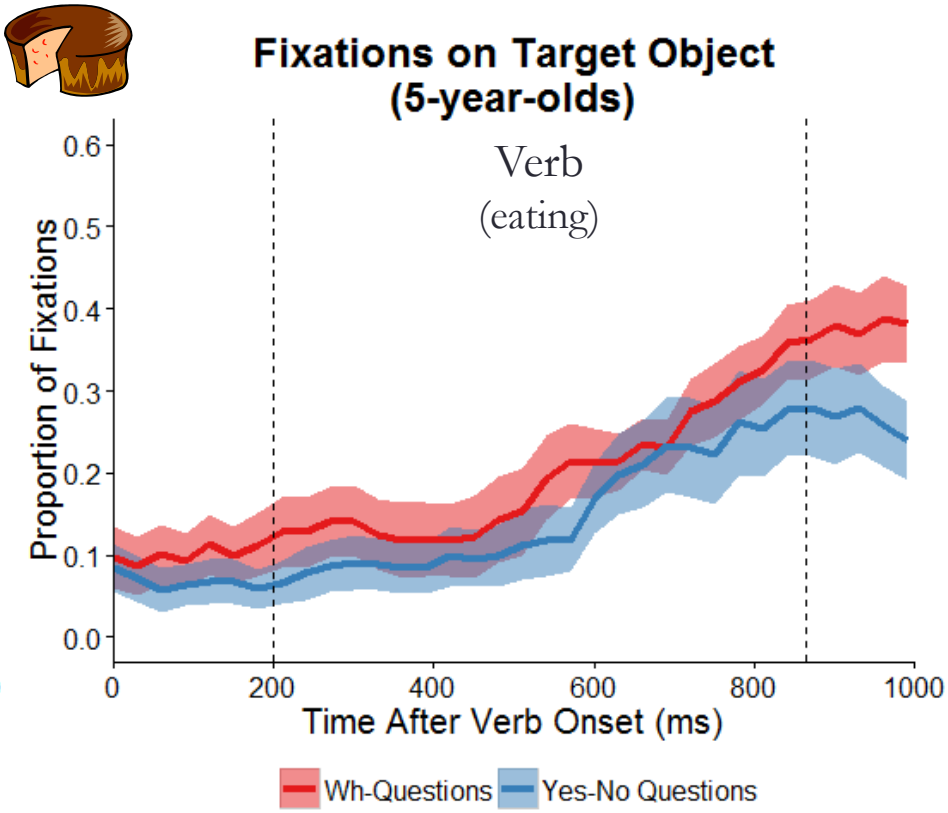
Verb region: 5-year-olds



- Similar increase in fixations on the target object in **both conditions**

Verb region: Both age groups



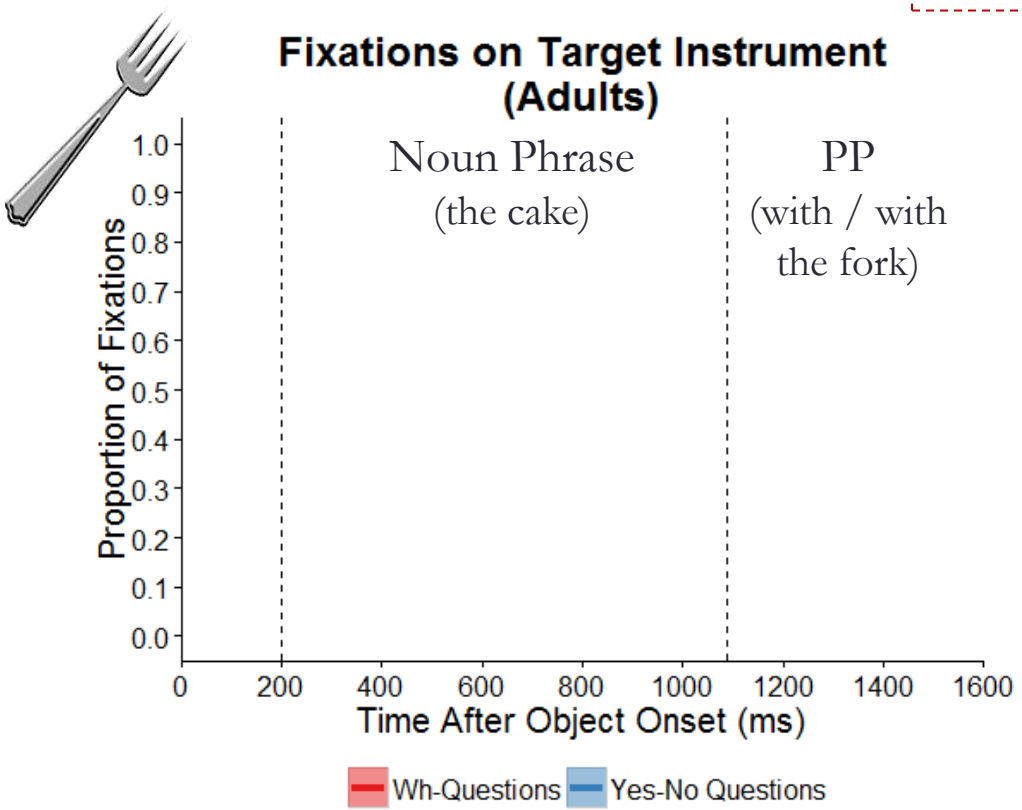


- **Significant interaction of age group & question type ($p < 0.001$)**
- Significant pairwise comparisons – adults ($p < 0.001$); 5-year-olds ($p < 0.001$)

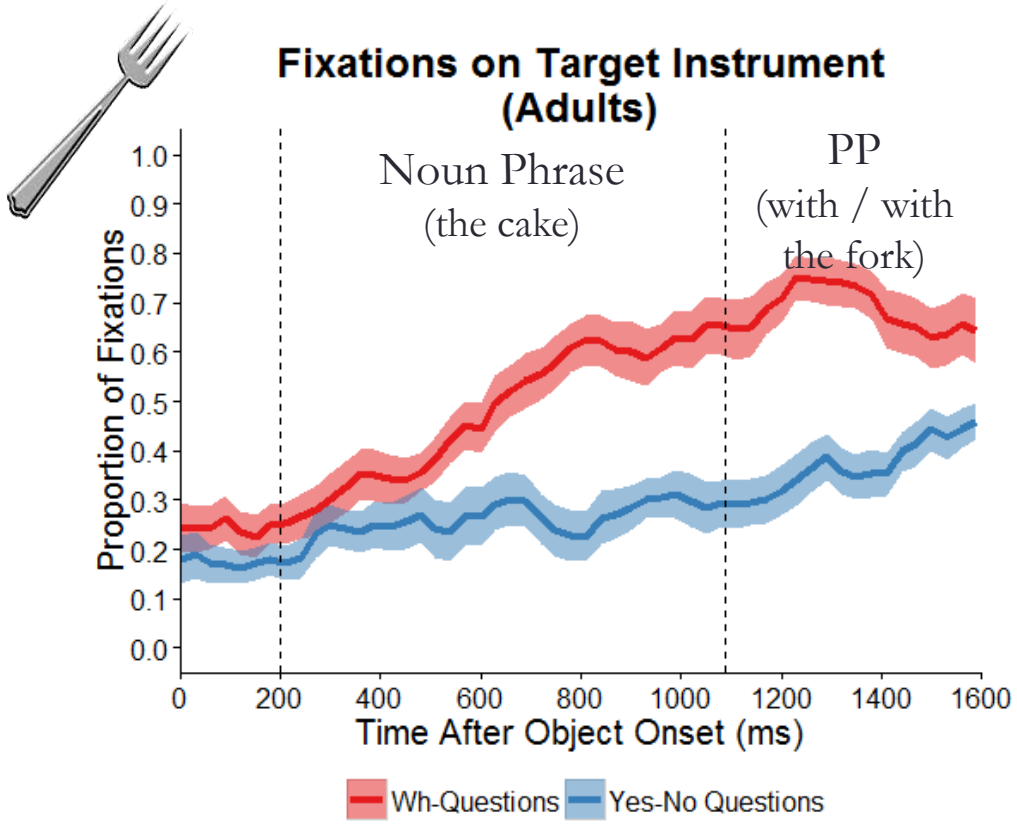
Evidence for structural predictions

- 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 __ ?

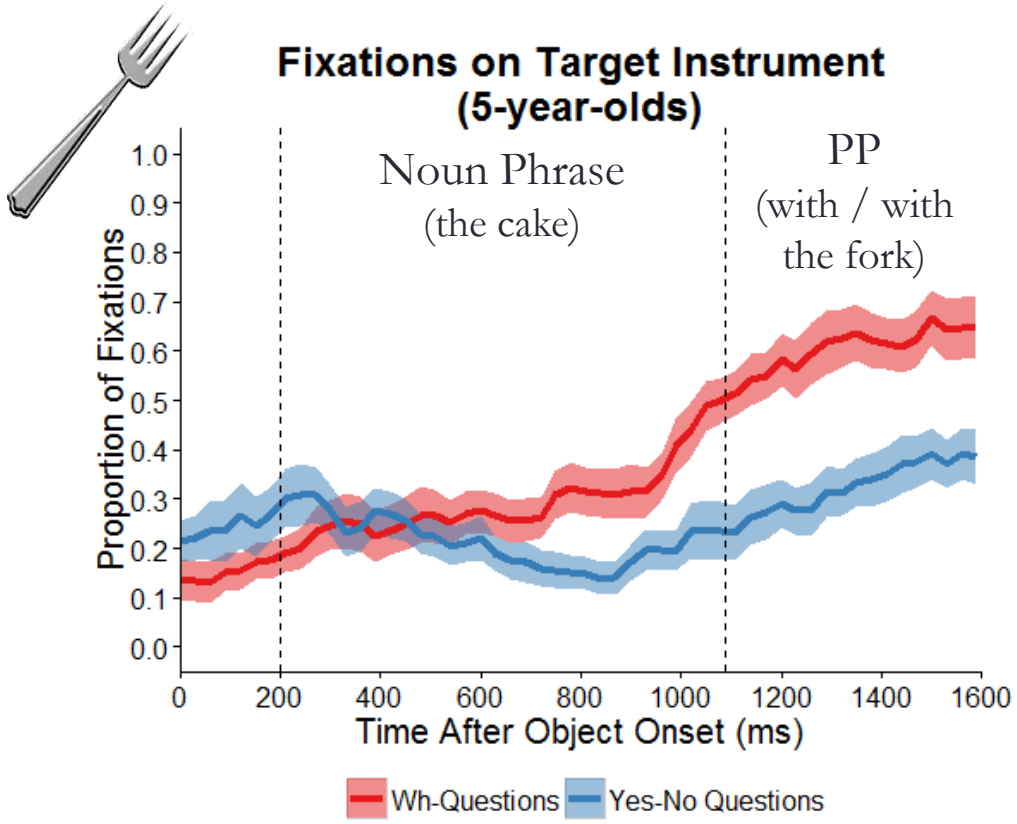


NP region: Adults



- Greater increase in fixations on the target instrument during ***wh*-questions**

NP region: 5-year-olds



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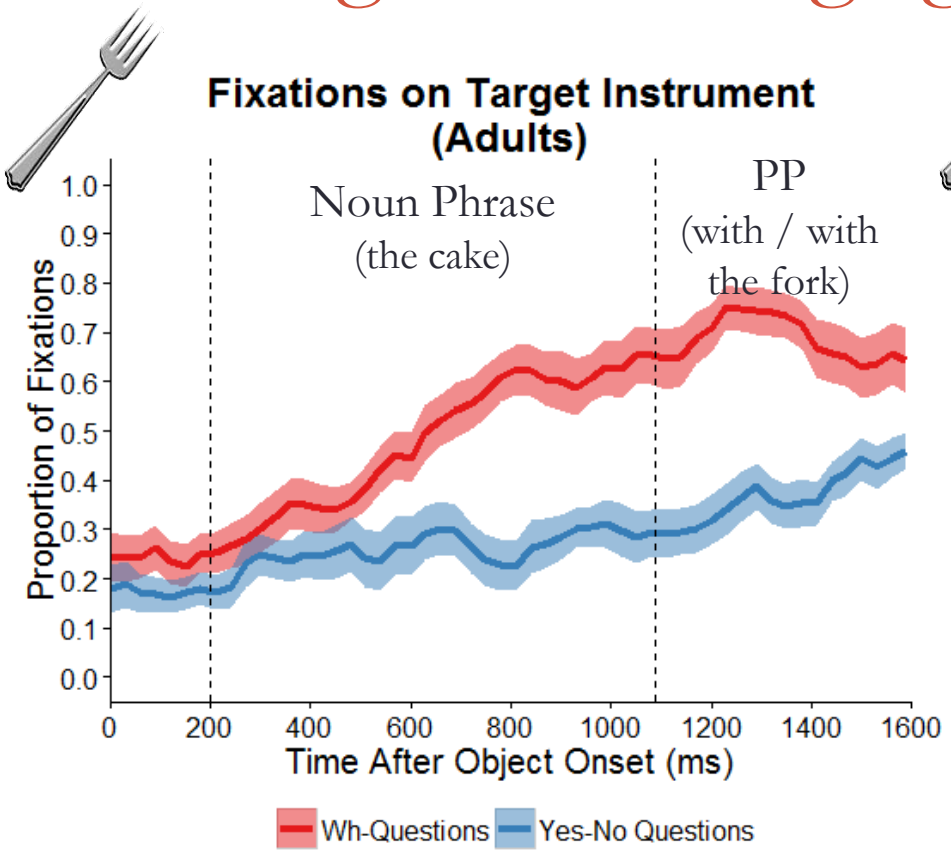
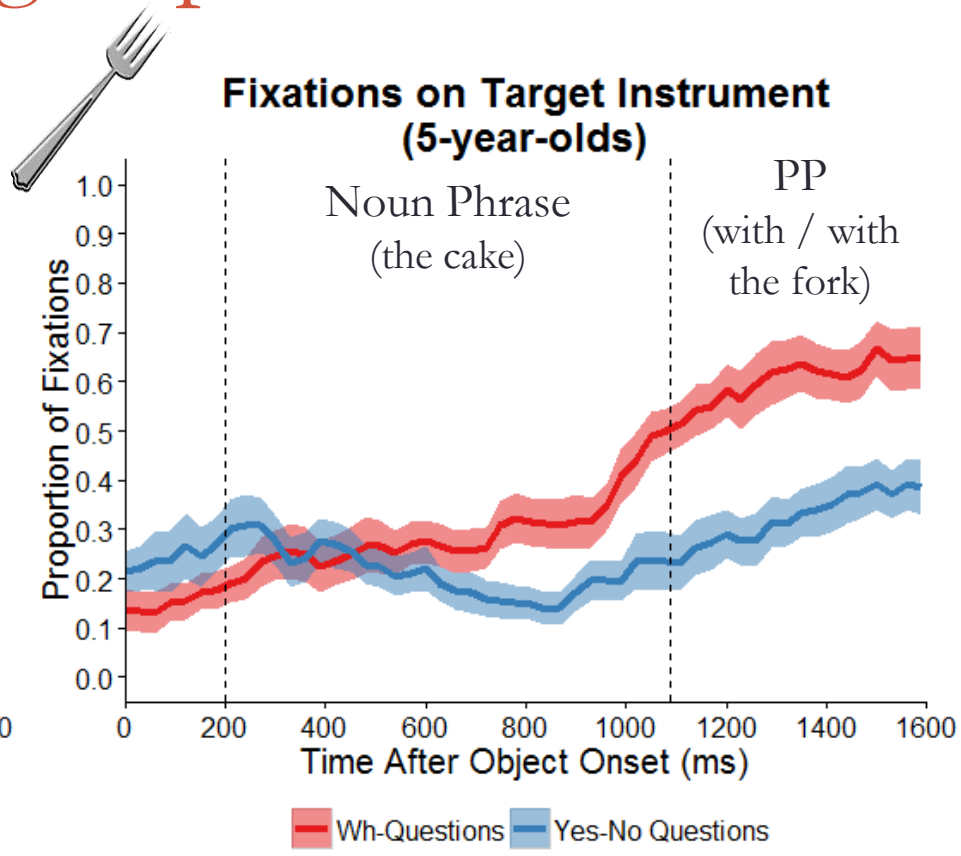
NP region: Both age groups





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

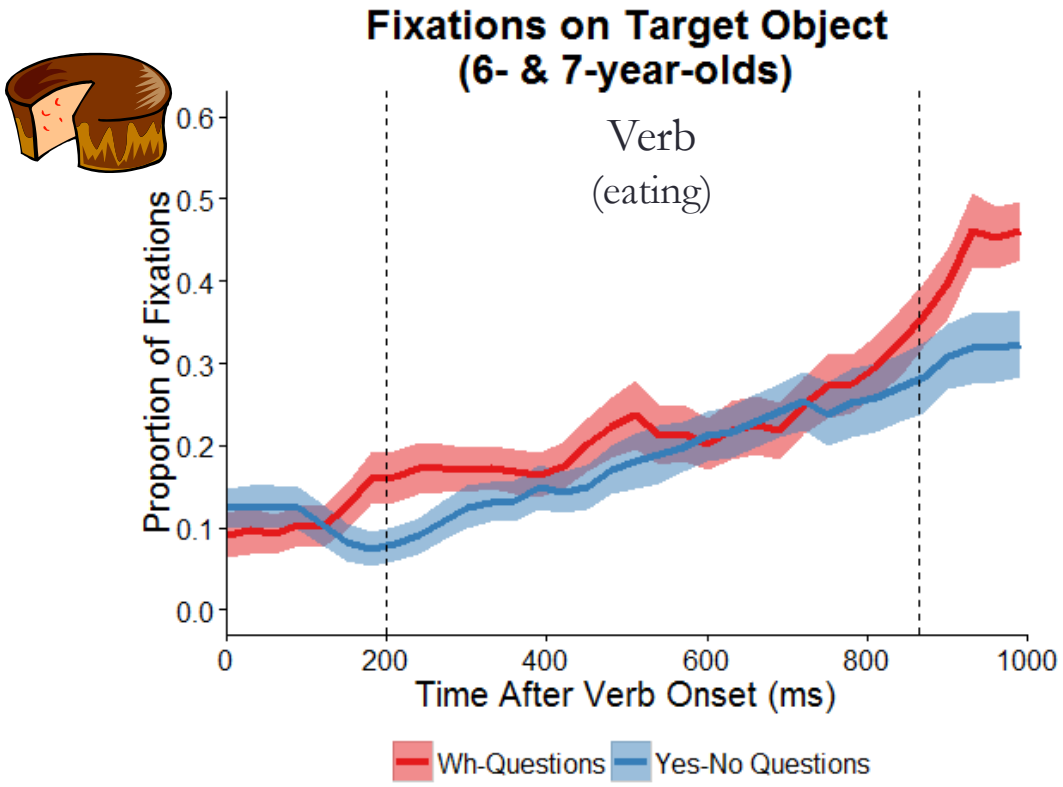
Experiment 2: Older children

- 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?

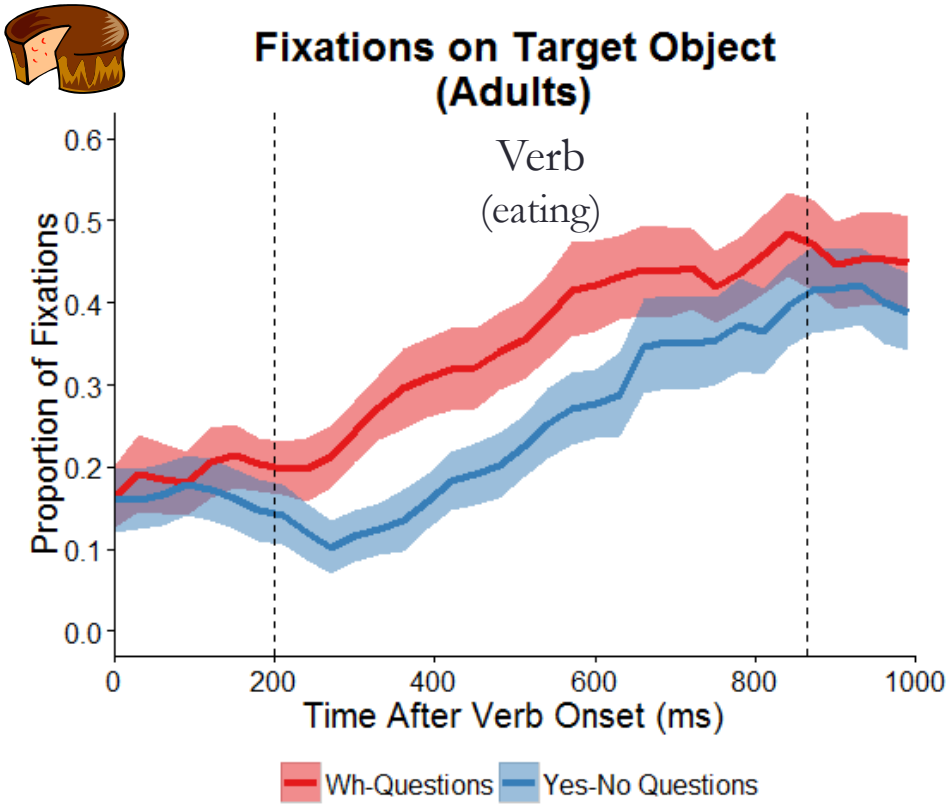
- 35 native English speaking children between the ages of 6;0 and 8;0
  - 19 children between the ages of 6;0 and 7;0 (mean = 6;4, 12 females)
  - 16 children between the ages of 7;0 and 8;0 (mean = 7;5, 8 females)

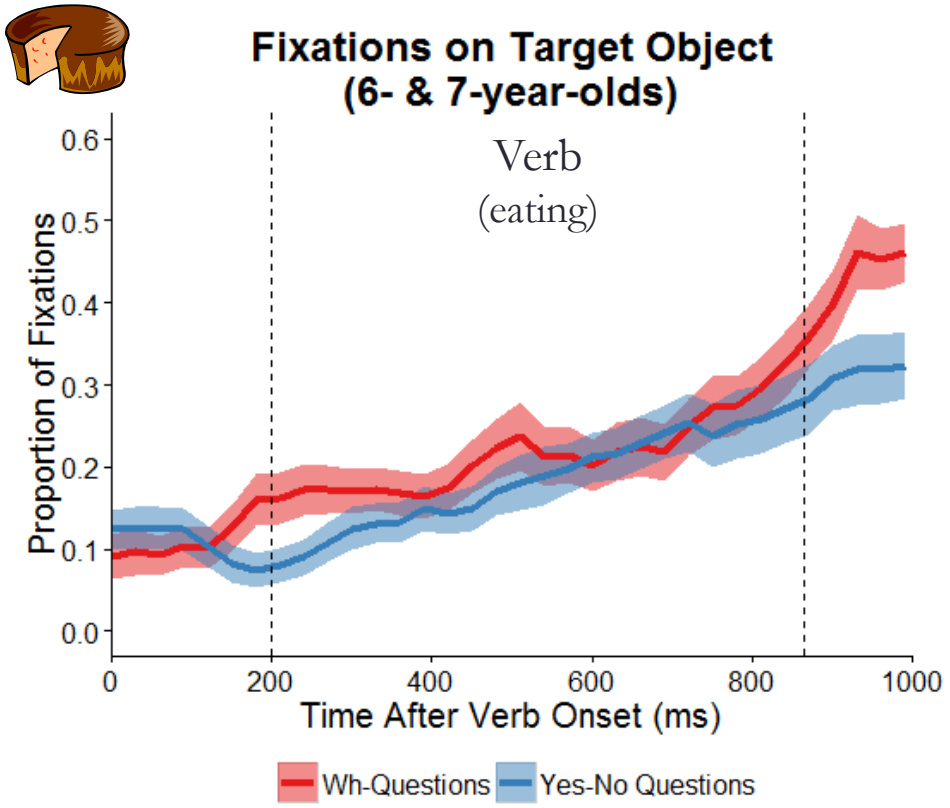
Verb region: 6- & 7-year-olds



- No significant difference between the 6- & 7-year-olds
- Similar increase in fixations on the target object in **both conditions**, like 5-year-olds

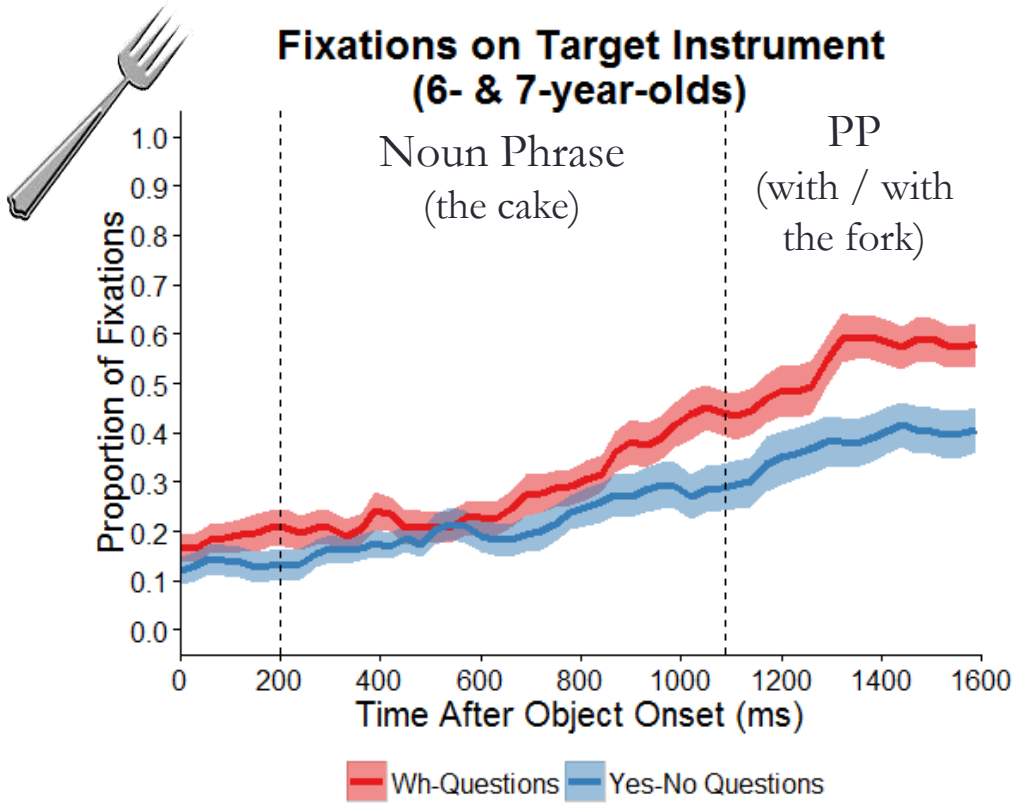
Verb region: Comparison to adults





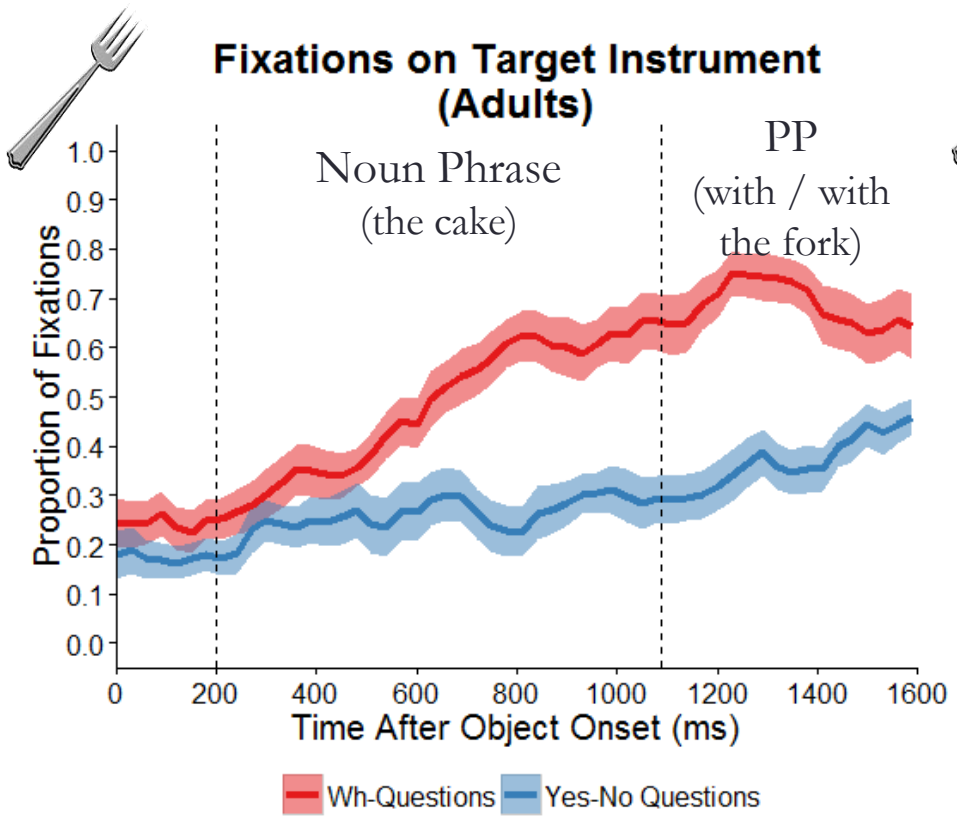
- **Significant interaction of age group & question type ($p < 0.001$)**
- Significant pairwise comparisons – adults ($p < 0.001$); 6- & 7-year-olds ($p < 0.001$)

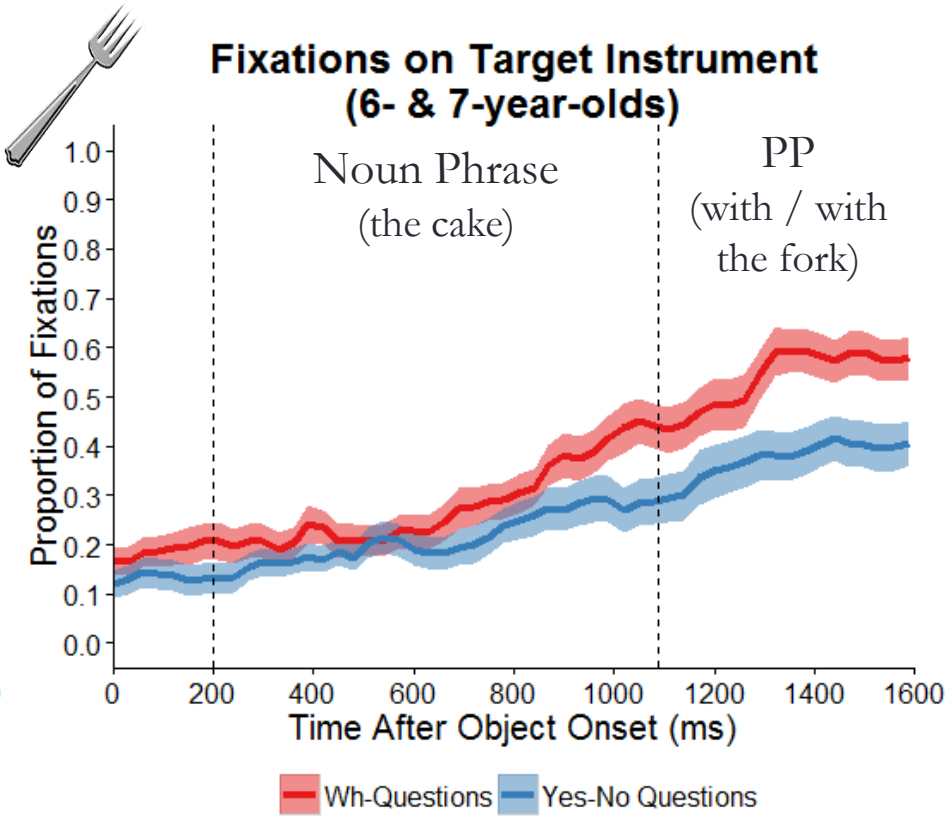
NP region: 6- & 7-year-olds



- No significant difference between 6- & 7-year-olds
- Greater increase in fixations on the target instrument during ***wh*-questions**, like 5-year-olds

NP region: Comparison to adults





- 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

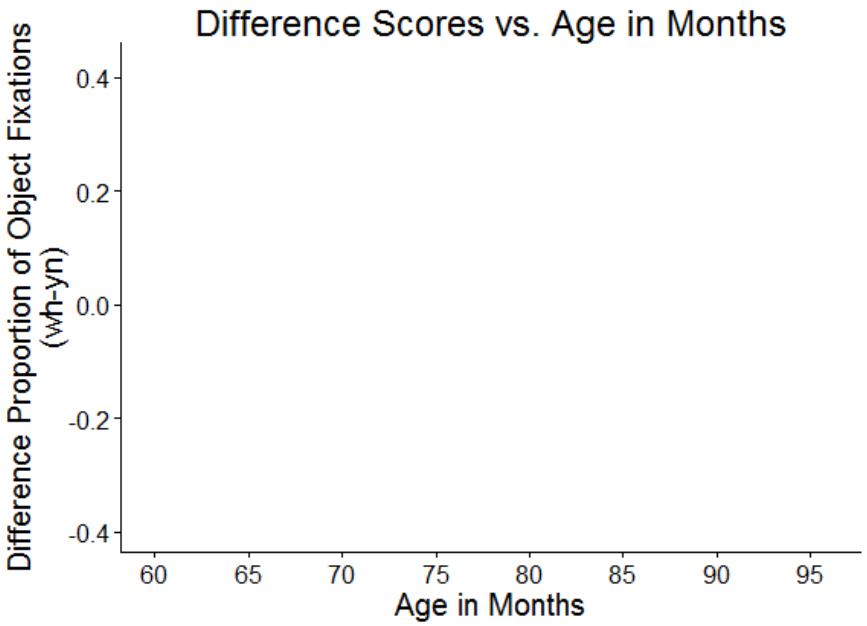
- Are there other relevant factors?
  - Age in months
  - Comprehension vocabulary size
    - Measured using raw score on Peabody Picture Vocabulary Test (PPVT™-4)

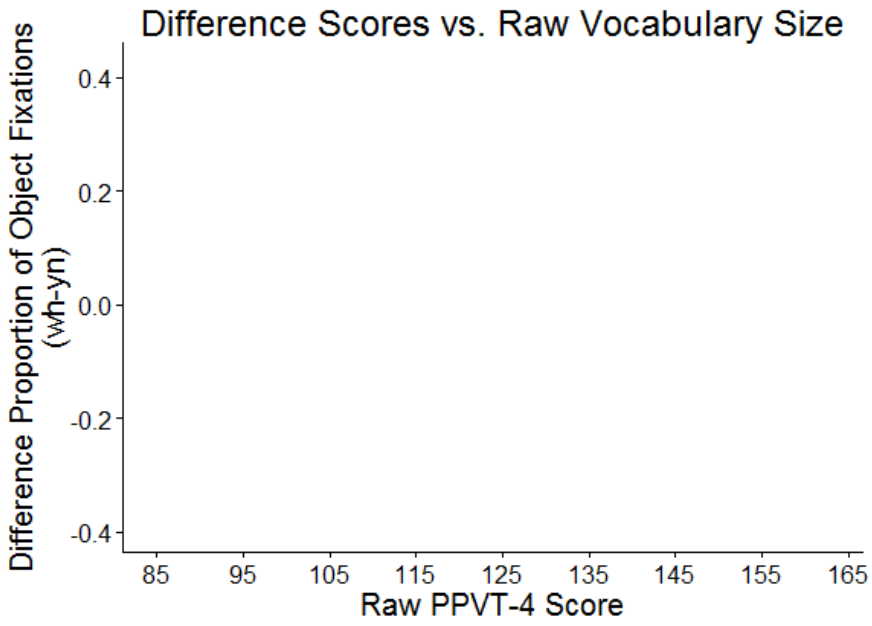
      (see Borovsky et al. 2012; Mani & Huettig 2012; Nation et al. 2003)
  - Language experience

Other factors: Age & vocabulary size

- Difference scores (verb region)

  Proportion object fixations in *wh*-questions – Proportion object fixations in *yes-no* questions

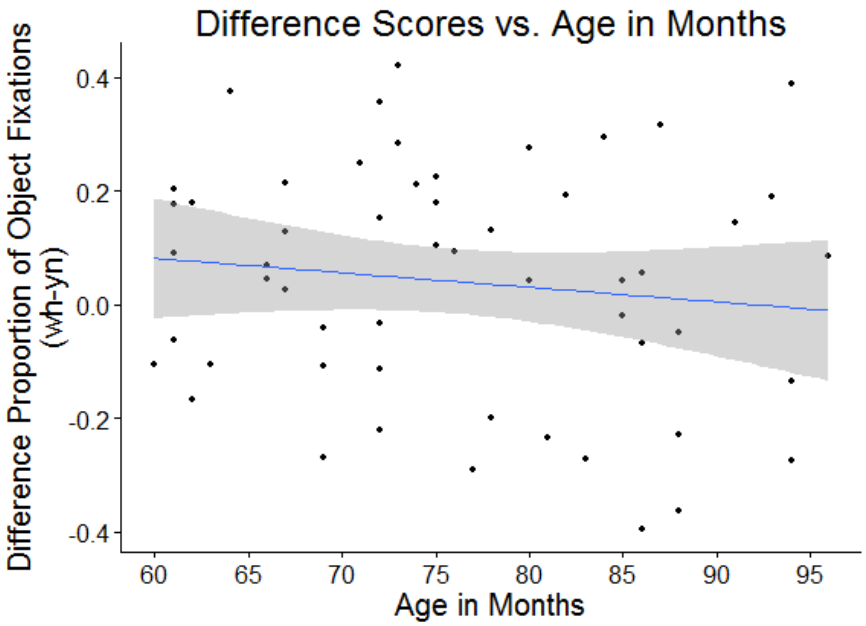


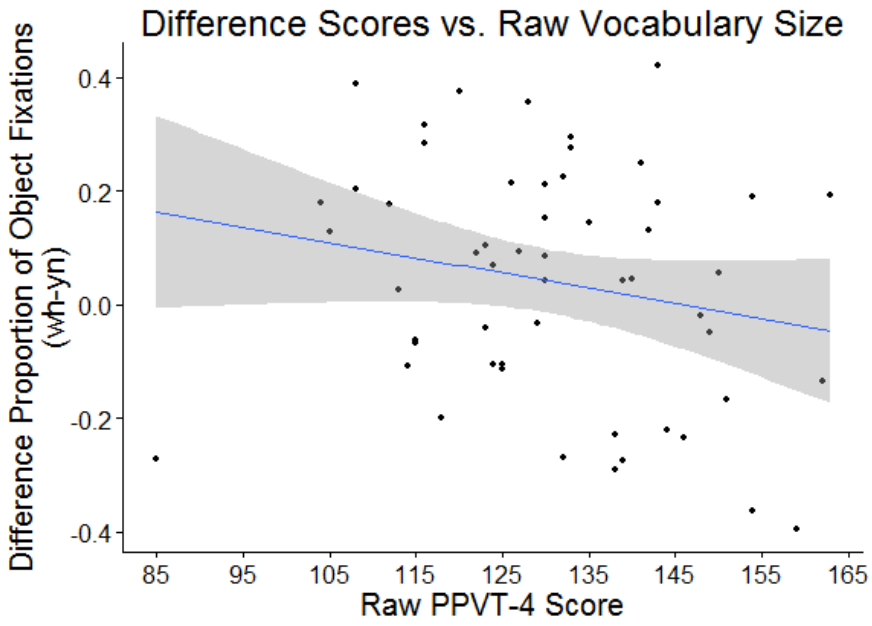


Other factors: Age & vocabulary size

- 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

Object Gaps			Preposition Gaps			
Overt PP	No PP	**Total**	Overt Object	No Object	**Total**	Total
1,192 33.1%	2,022 56.2%	**3,214** **89.3%**	81 2.3%	303 8.4%	**384** **10.7%**	3,598

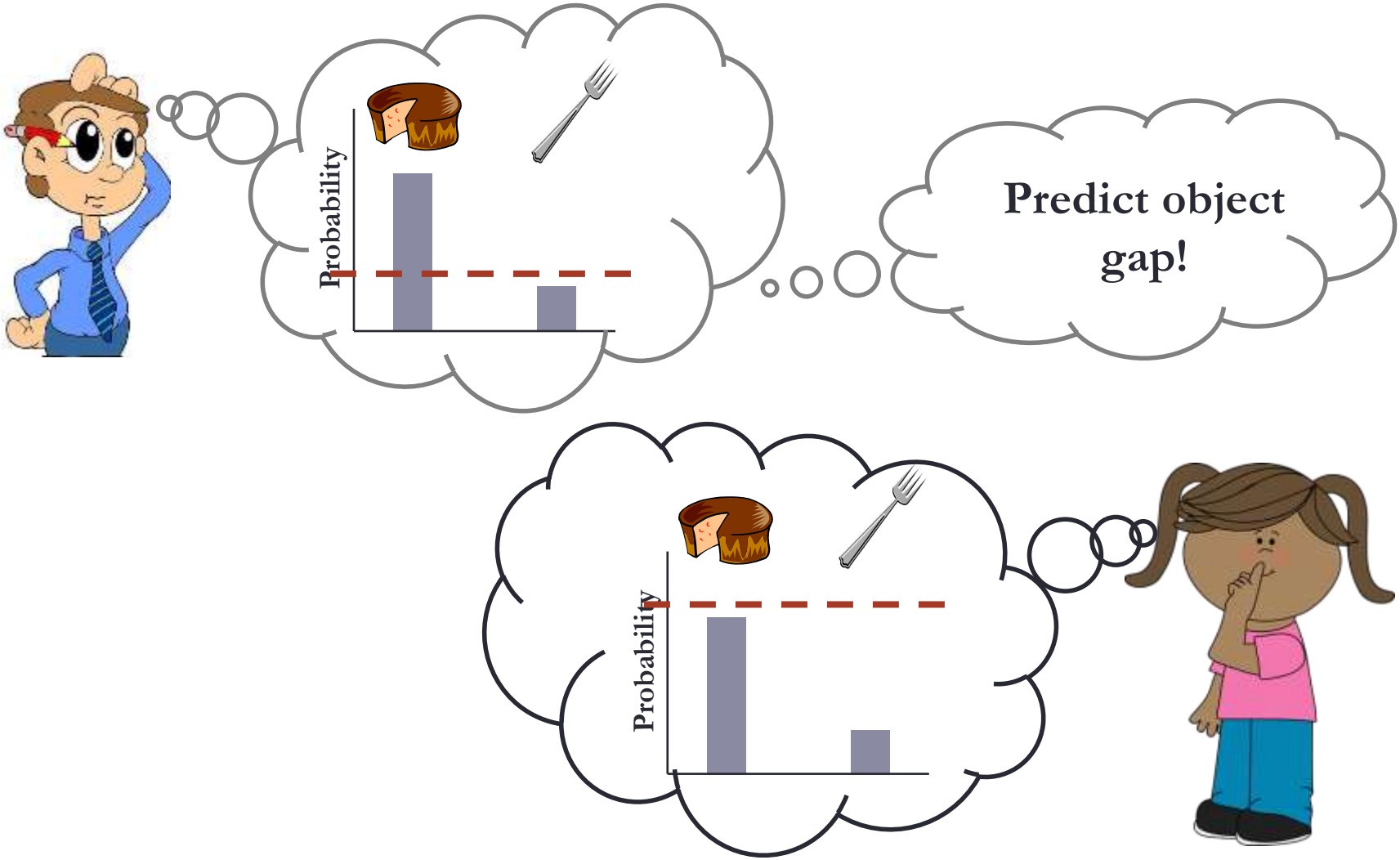
(Abe, Adam, Naomi, Nina, & Sarah Corpora; CHILDES)

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)

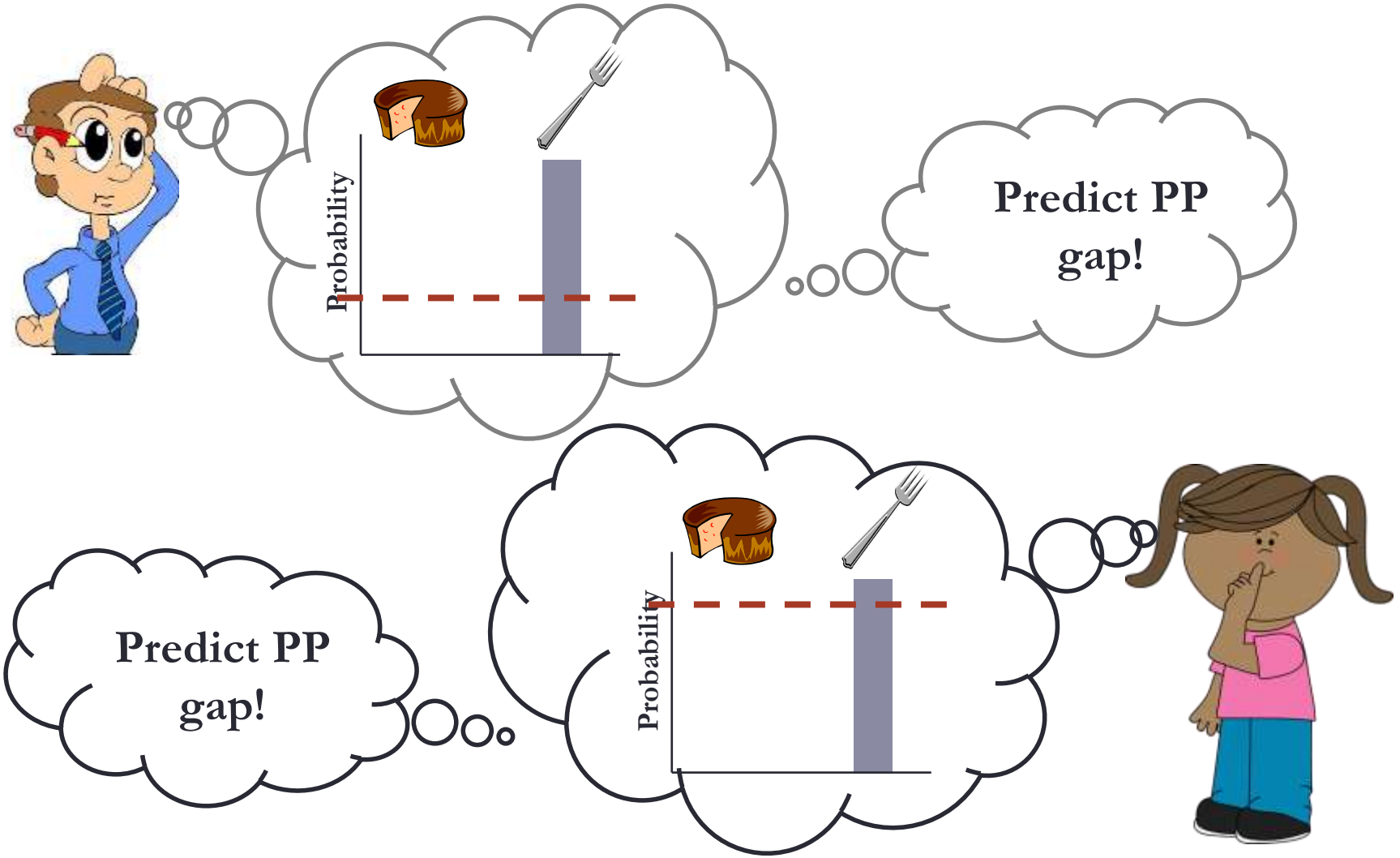
Conservative prediction strategy: Verb region

Can you tell me what Emily was **eating**…



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!

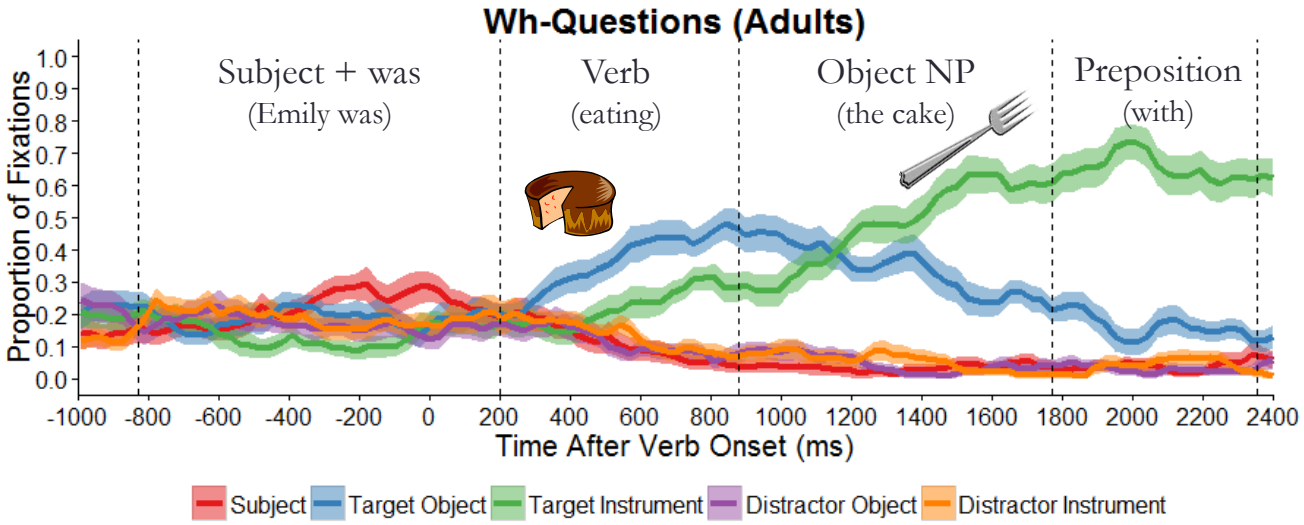
- This work supported by NSF #BCS-1423117 to Akira Omaki

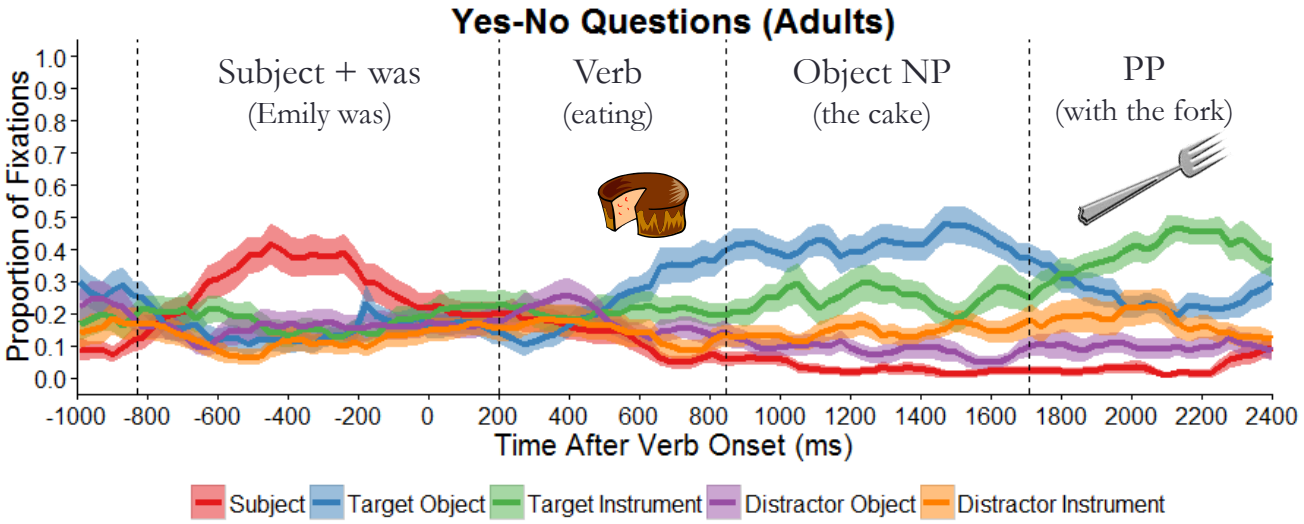
- Thanks to the many people that have helped with this project:
  - My participants and their parents
  - Katherine Simeon
  - Will Harrison
  - Melinh Lai
  - Language Processing & Development Lab
  - Colin Wilson

Questions?

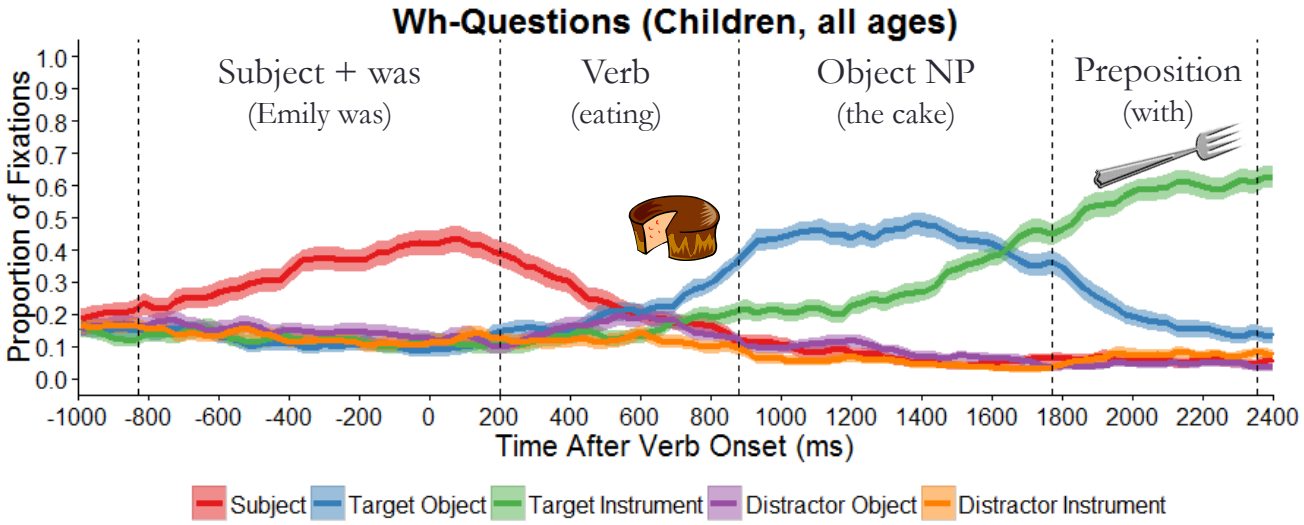
Sample question audio

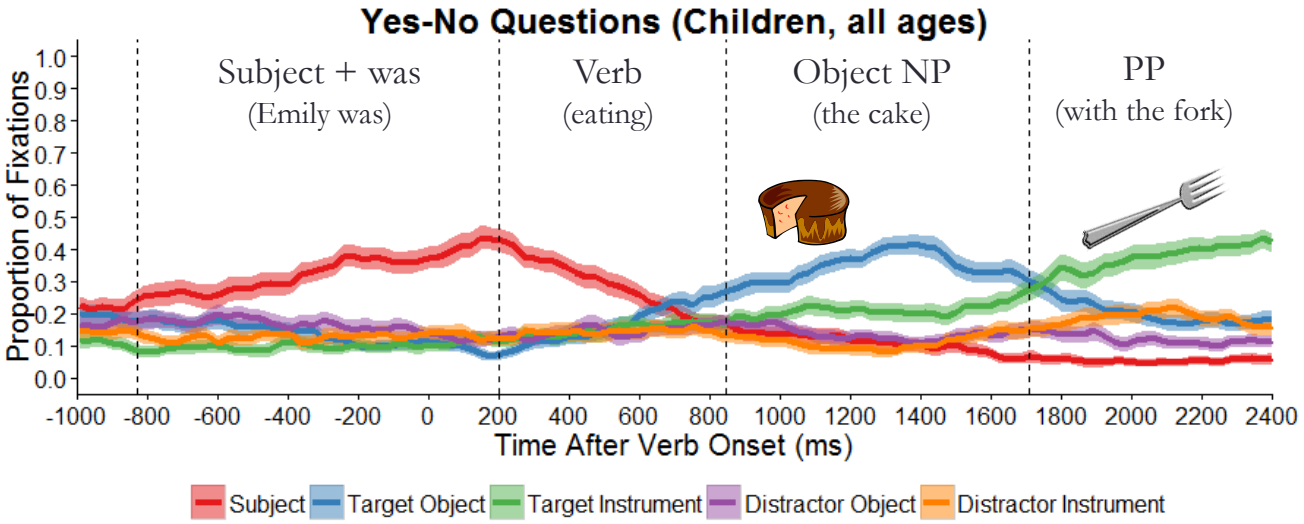
Timecourse: Adults



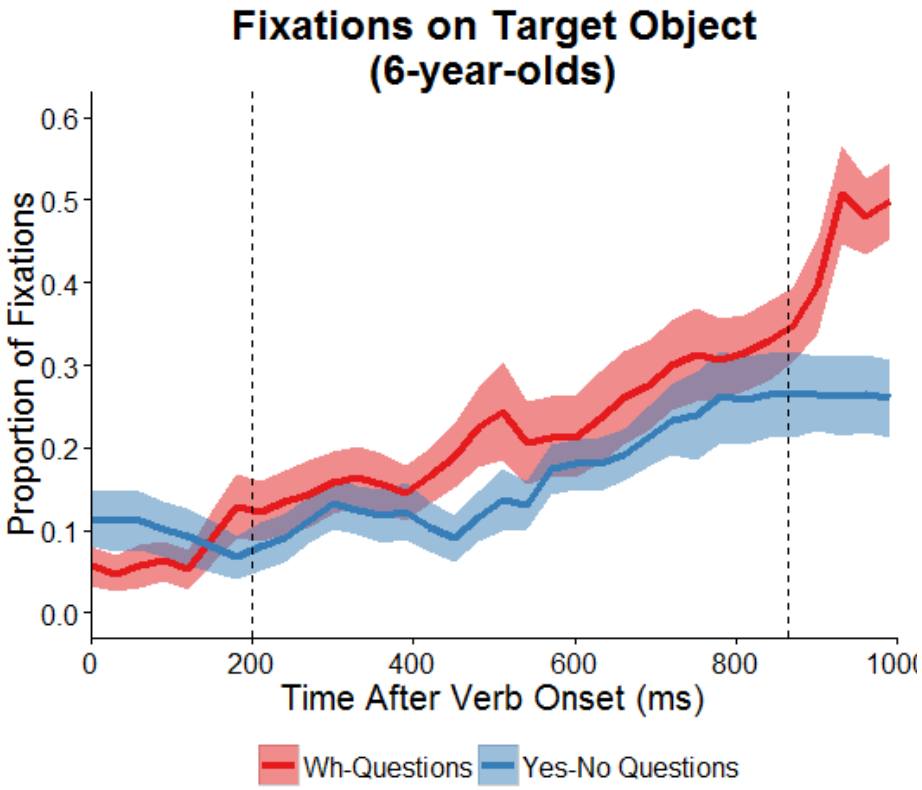


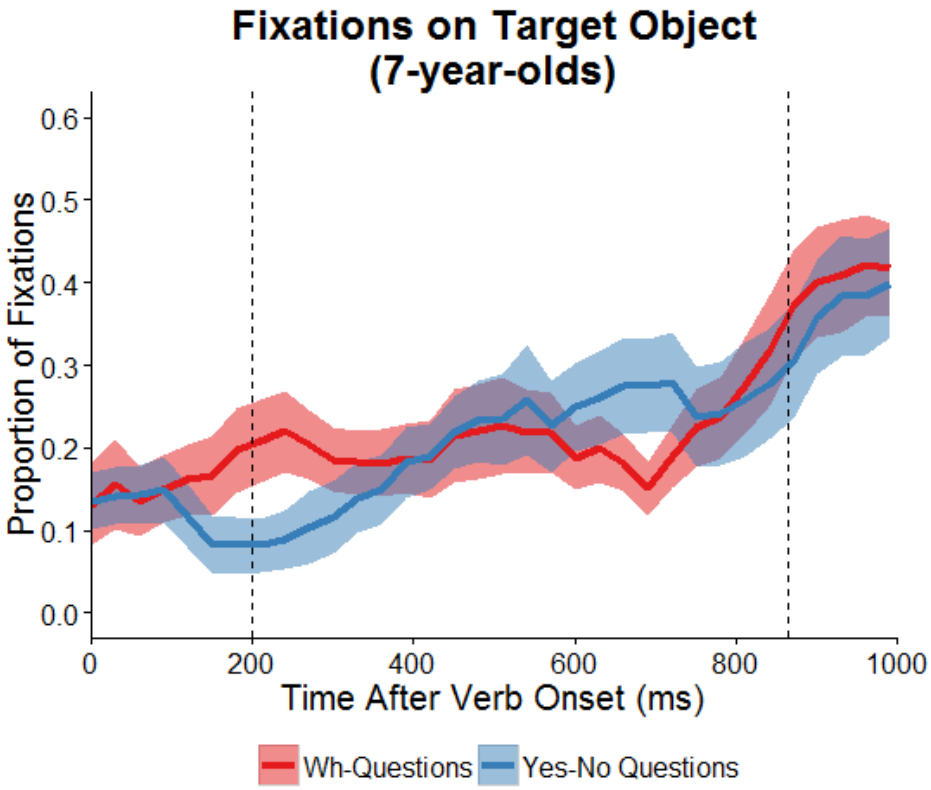
Timecourse: 5- to 7-year-olds



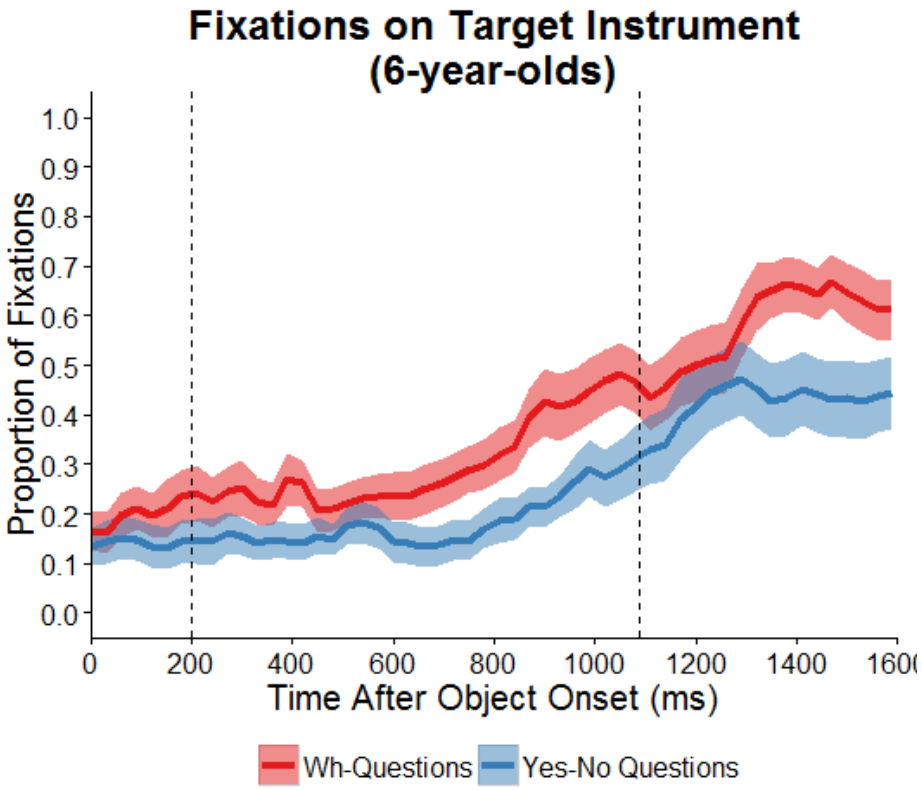


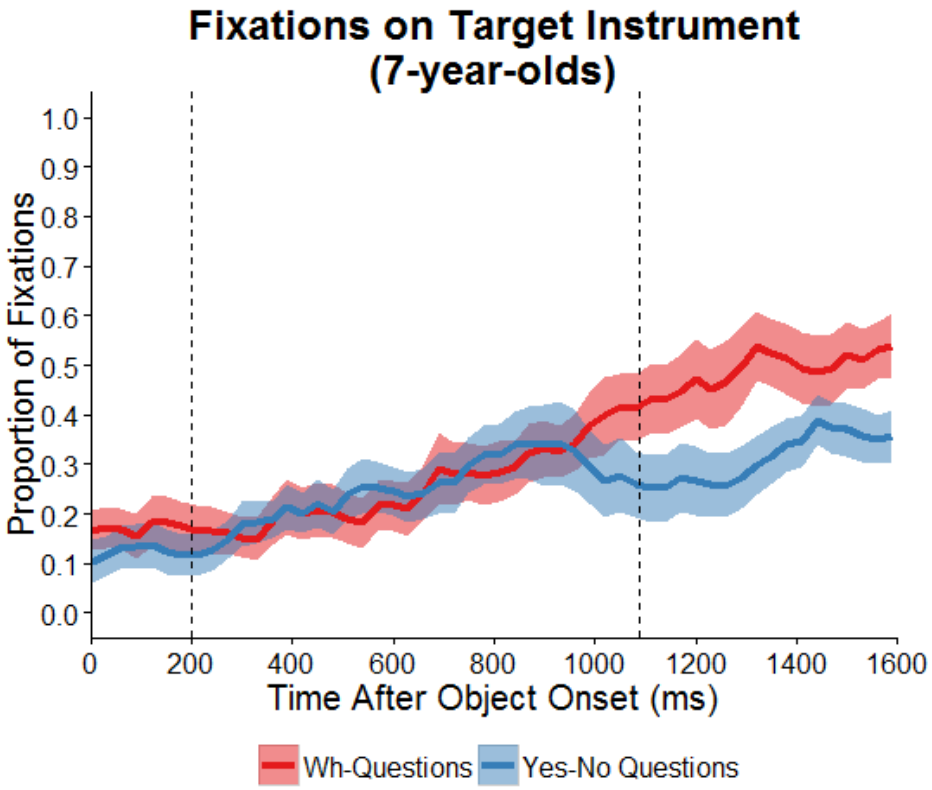
Verb region: 6- & 7-year-olds





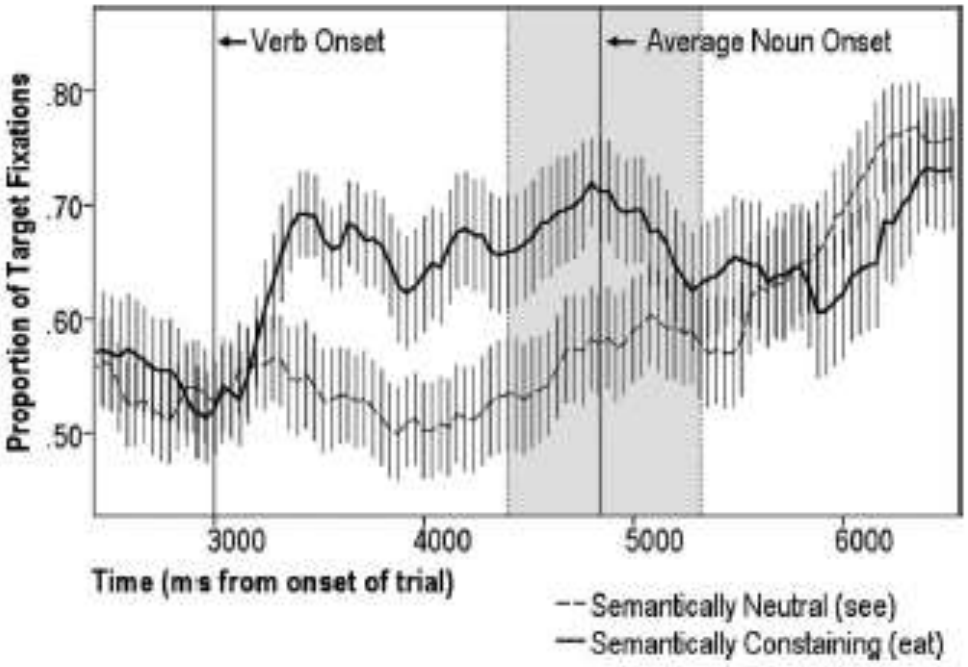
Direct object region: 6- & 7-year-olds





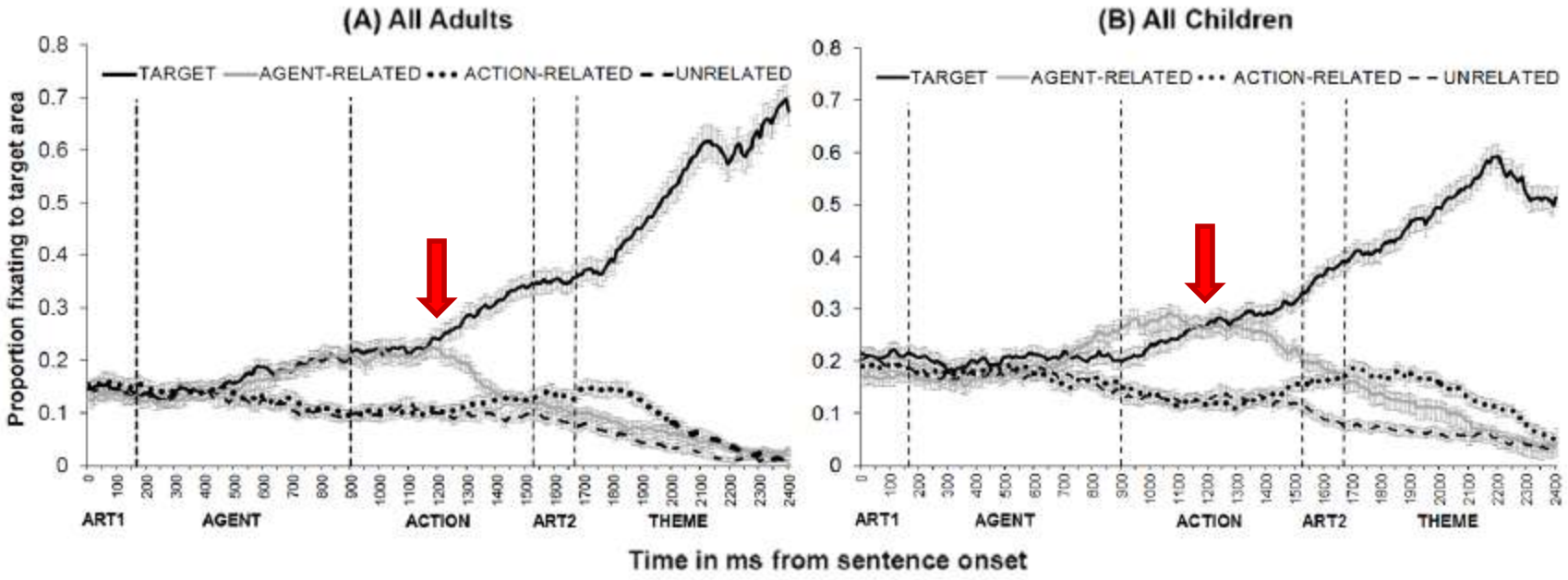
Mani & Huettig 2012: Anticipatory fixations

- 2-year-olds' make anticipatory fixations on likely object in same timecourse as adults'
  - The boy *eats* the big <u>cake</u>. (constraining)
  - The boy *sees* the big <u>cake</u>. (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

Object Gaps	Preposition Gaps	Total
471	59	530
86.1%	**13.9%**	100%