The Time Course of Filler-Gap Dependency Processing in the Developing Parser

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1. INTRODUCTION

Goal of the Study

The adult parser makes structural commitments prior to clear bottom-up evidence. The development of these predictive mechanisms, however, has not been investigated. This study asks whether children make the same structural predictions as adults by examining 5-year-olds' real time processing of *wh*-questions.

Filler-gap dependency processing:

(1) **What** did John paint the door with ___?
      filler   gap

- Upon processing a filler, the adult parser actively completes filler-gap dependencies by predicting a gap in the first possible syntactic position, i.e., the direct object of *paint* in (1), in advance of bottom-up evidence [1-4]. Do children also utilize the active gap filling strategy?

Child predictions in the visual world:

- Both adults and children as young as 2;0 make anticipatory fixations on an appropriate object based on verb information [5-7]. However, these fixations could be driven by the conceptual association between a verb and object and not a prediction of the direct object position.
    - Comparison of fixations on cake in…
      The boy will *eat* the cake.   vs.
      The boy will *move* the cake.

The present visual world study:

- Given that children acquire requisite grammatical knowledge of filler-gap dependencies (e.g., [8]) & make adult-like predictions in verb-based visual world studies, it is plausible that they would be able to actively complete filler-gap dependencies.

- Previous studies have argued that children utilize an active gap filling strategy [9,10], but did not provide time course evidence. The present study aims to fill this gap in the literature.

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2. EYE-TRACKING STUDY

Design Participants were told a story with an accompanying display and then asked a question about that story.

Participants

Children: 12 5-year-olds, mean age = 5;5, range 4;8 – 5;2
Adults: 27 Johns Hopkins University undergraduates

Stories (n = 20) Animated stories with 2 events each with an associated verb, direct object, & instrument. 2 events

are critical to prevent participants from determining the content of the question before processing the verb (see [3] and [4]'s revisions).

Event 1: eat cake with fork
Event 2: wash dishes with sponge

Target Questions (n = 10; 5 *wh*, 5 *yes-no*)
Can you tell me…
      what Emily was eating the cake with ___?   (*wh*)
      if Emily was eating the cake with the fork?   (*yes-no*)
The *wh*-question contains a filler-gap dependency, while the *yes-no* question does not. The *yes-no* condition serves as a control for the verb-based fixations found in [5-7].

Filler Questions (n = 10; 5 *wh*, 5 *yes-no*)
Can you tell me…
      what Emily was eating ___ with the fork?   (*wh*)
      if Emily was eating the dishes with the fork?   (*yes-no*)

Eye-tracking EyeLink 1000 Remote eye-tracker (SR Research, Toronto, ON)

Predictions

- *Active gap filling* – Because 2 objects are displayed, the verb must be processed before the object associated with *what* can be determined. A greater proportion of fixations on the target object during the verb region (mean duration = 450ms) in the *wh*-condition indicates active gap filling.

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3. RESULTS

Accuracy: Adults were 99% accurate (1 adult missed 1 filler question). 5-year-olds were 95% accurate; no child had an accuracy < 85%.

Adult Fixation Data
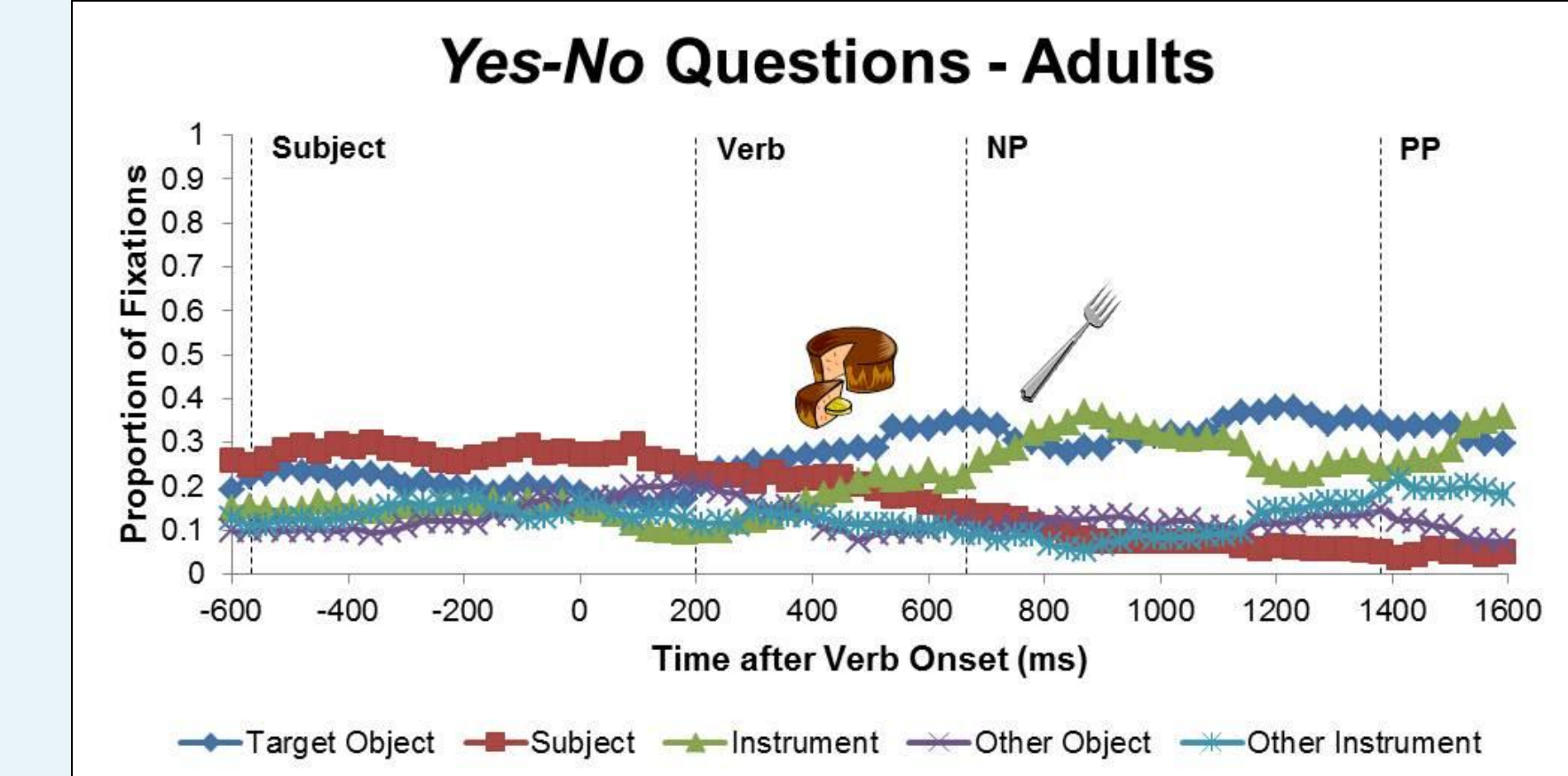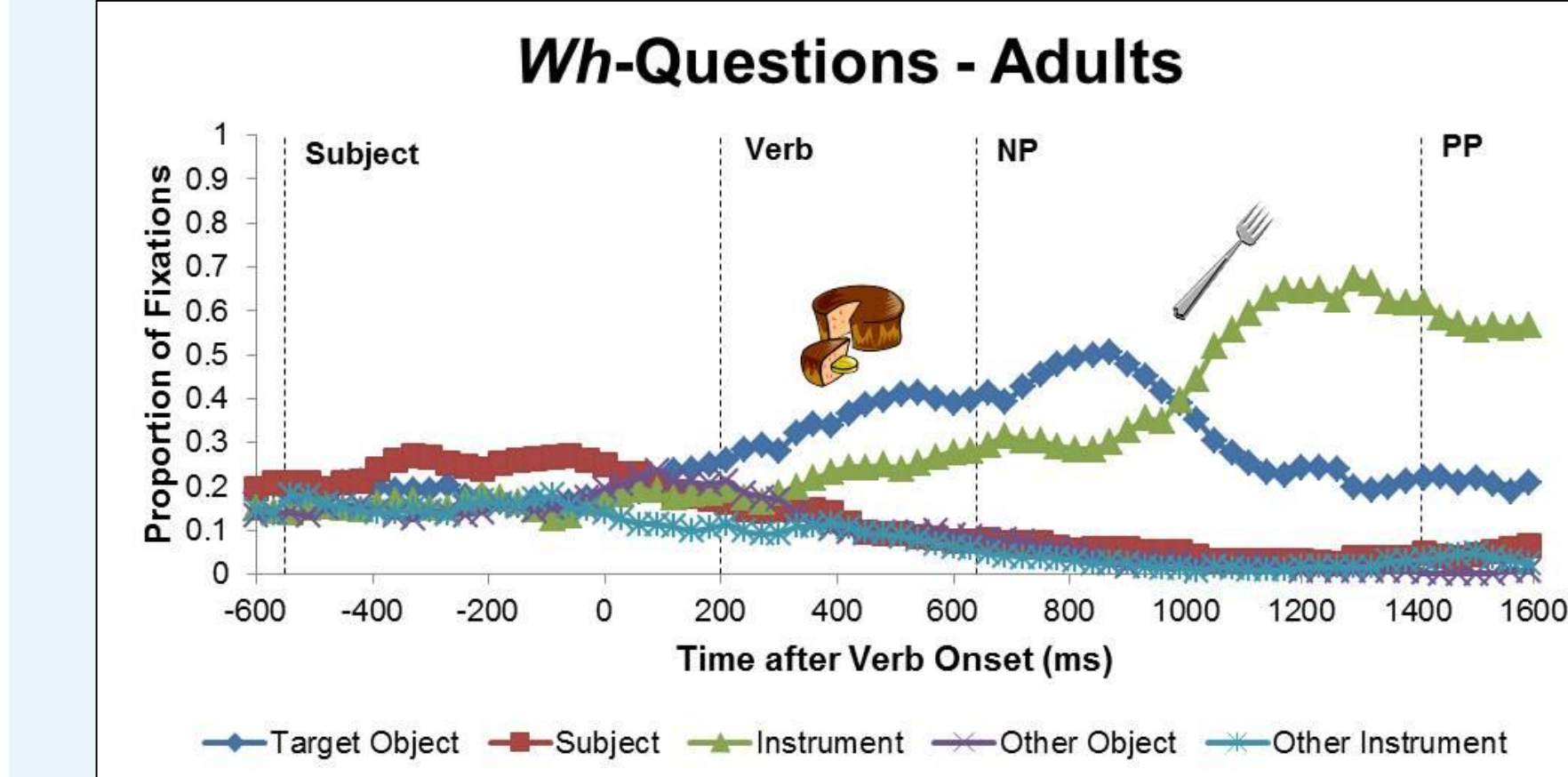
Child Fixation Data

Fixations on Target Object

Statistical Analysis

- Logit mixed models [12] on 30ms bins in the verb region, i.e., 200-650ms after verb onset
    - Fixed effects: age group, question type
    - Random intercepts: participants, items
- For bins 380 - 650ms, significant interaction between age group & question type (all p < 0.03, shaded on Age Comparison figure)
- Pairwise – Adults: More fixations on target in *wh*-condition (all p < 0.001, shaded on Adult figure)
- Pairwise – 5-year-olds: No reliable effect of question type (all p > 0.2)

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4. DISCUSSION & CONCLUSION

Main Findings: This is the 1st study to examine real time filler-gap dependency processing in children, and found that 5-year-olds are not actively predicting a gap location in this task.

Remaining Issues:

- Vocabulary size: Other studies [6,7] found an effect of vocabulary size on the timing of anticipatory fixations. We are currently re-running the present study & collecting vocabulary data (PPVT™-4) for a new set of 5-year-olds to address this issue.

- Indirect questions: Active gap filling may not be triggered in indirect questions due to larger processing demands.
    - [10,11] provide offline evidence for active gap filling in globally ambiguous direct *wh*-questions like *Where did Emily tell someone that she will catch a butterfly?* They found that 1) children associate the gap with the 1st verb in English, French & Japanese despite differing word orders, and b) this association bias persists even when this interpretation is blocked by a filled gap (*Where did Emily tell someone at the pool…*).
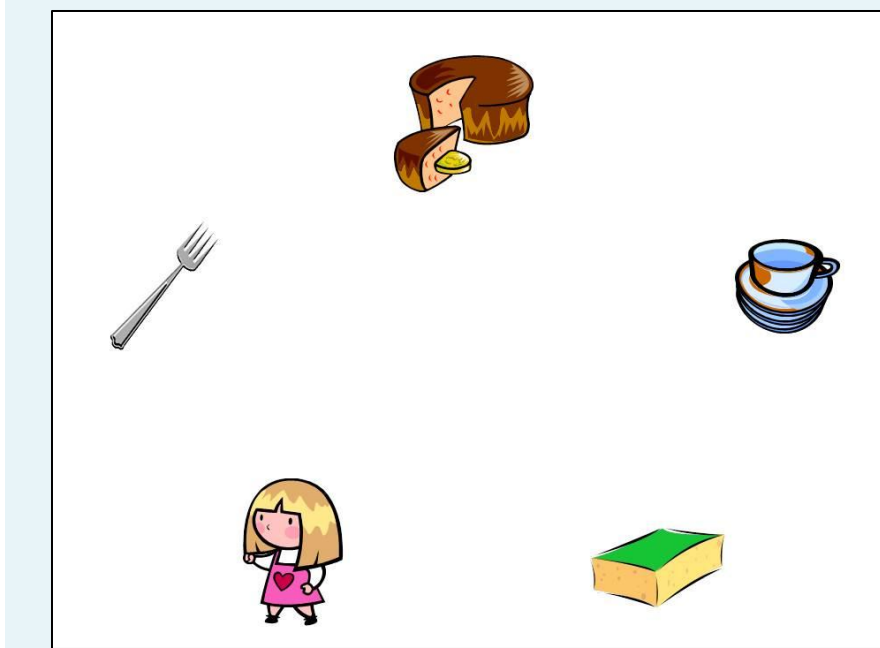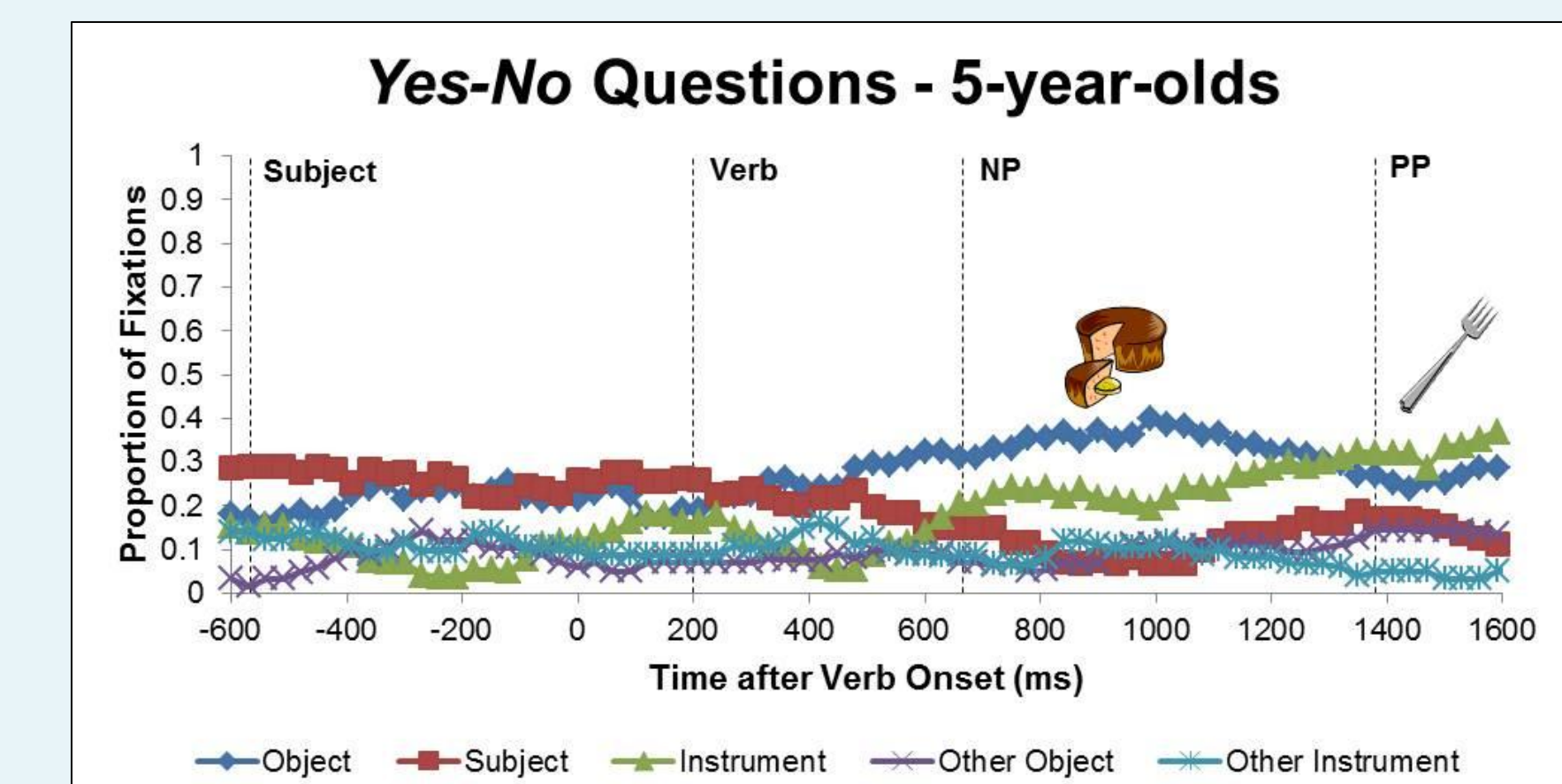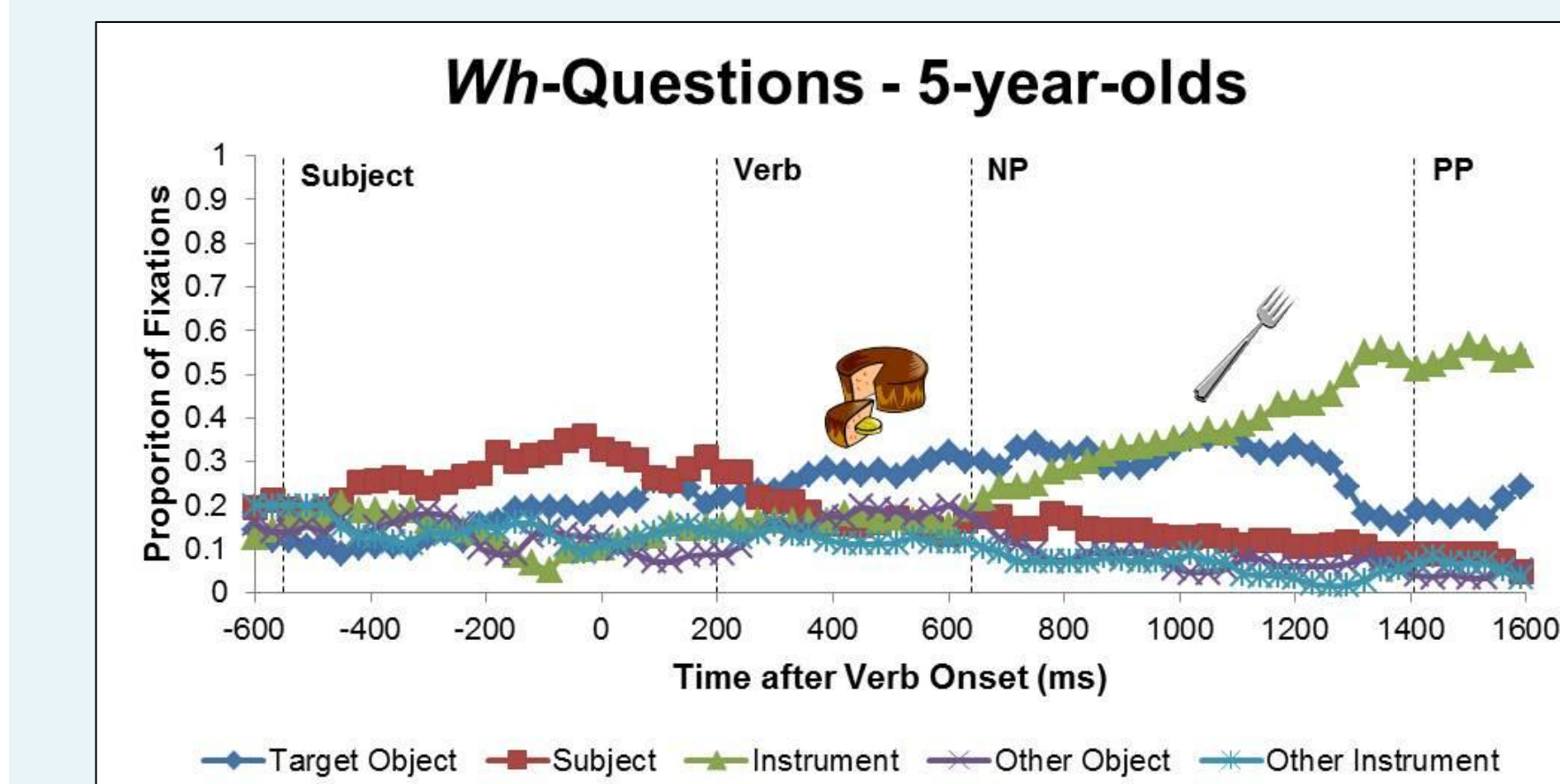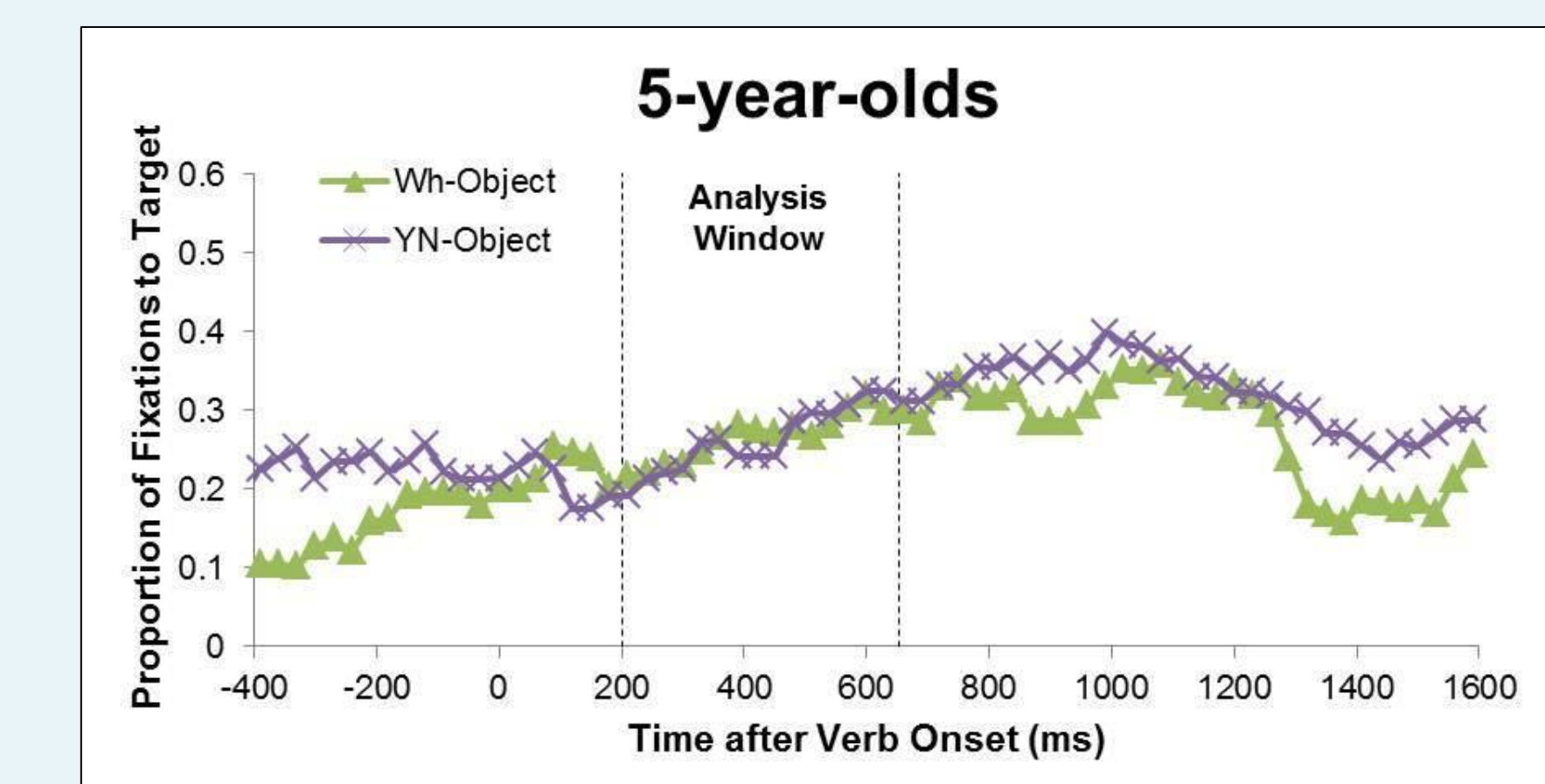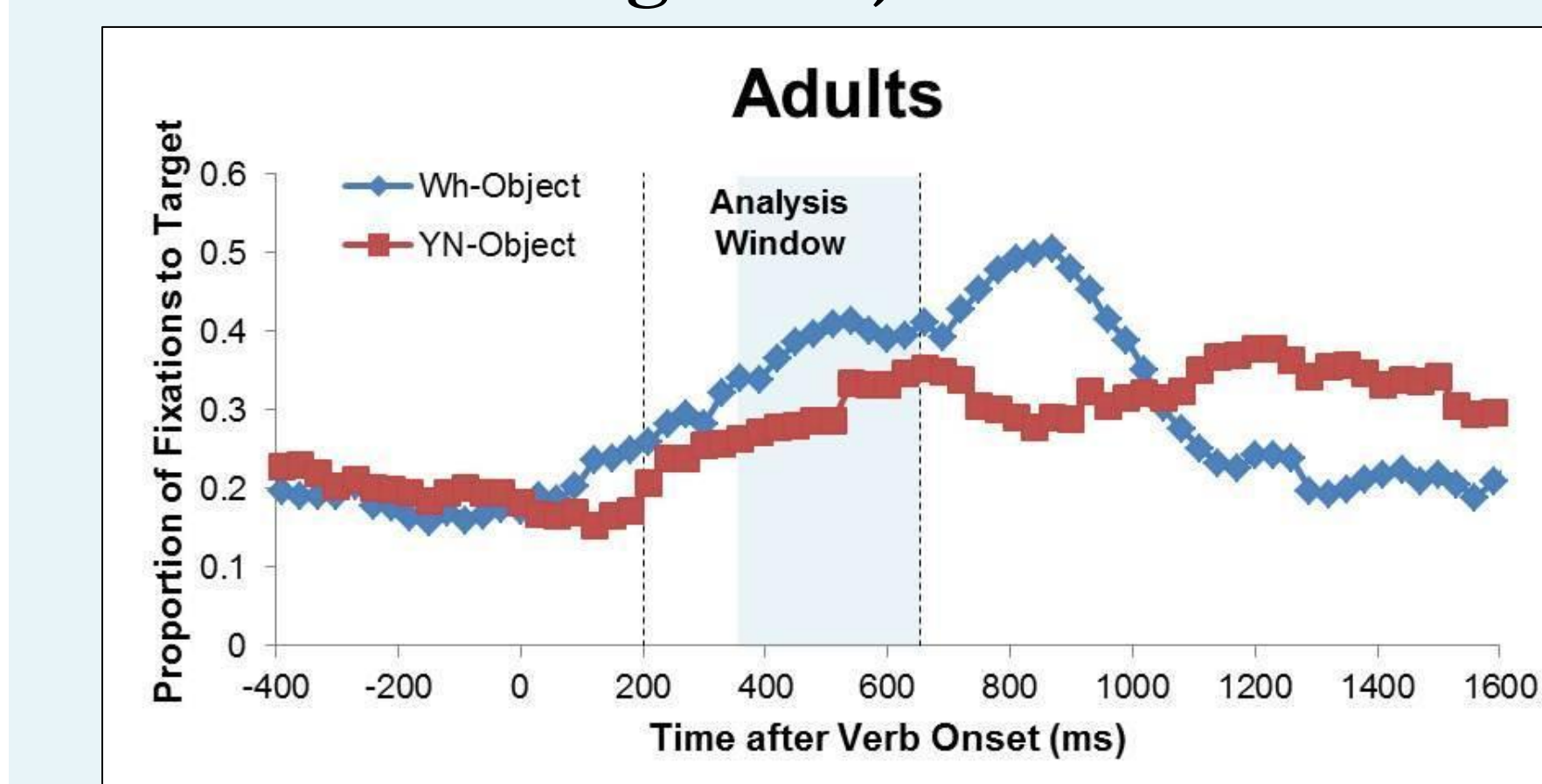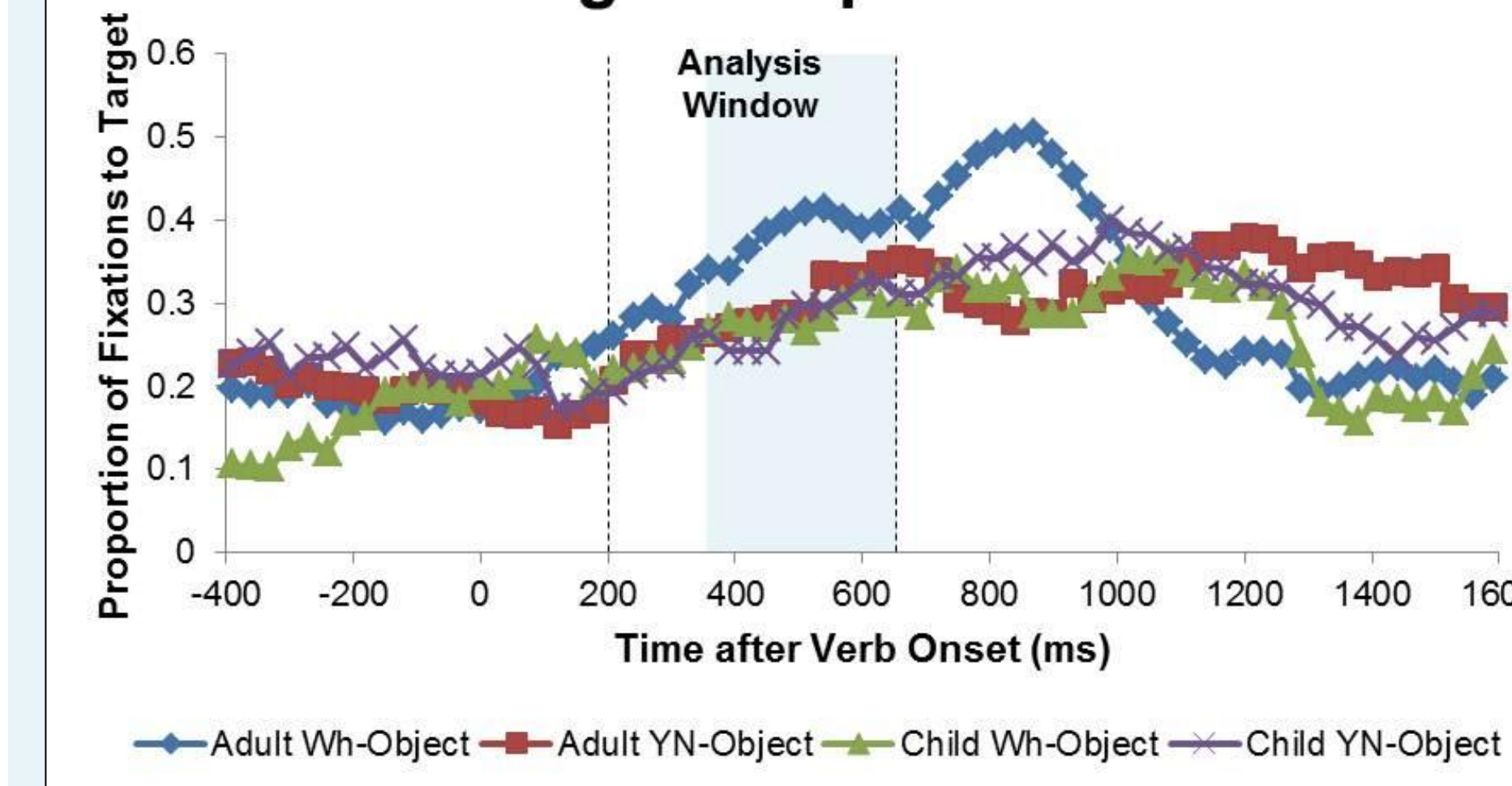   - Currently testing the direct question version: What was Emily eating the cake with?

Development of Predictions:

- The above results suggest that active gap filling must be learned. Thus, models of the parser must be able to explain the fact that 5-year-olds are not utilizing an active gap filling strategy.
    - These results are compatible with models that include a probabilistic component such that predictions are learned via exposure to distributional information, e.g., [13].
    - However, the preliminary distribution analysis of *wh*-questions with *what* indicates that there may be reliable distributional information to expect a direct object gap. Further distributional analyses are underway.

Object Gap	Preposition Gap	Double Object Gap	Total
630 (80.2%)	119 (15.1%)	37 (4.7%)	786

(Adam corpus, CHILDES)

- Processing long-distance dependencies requires a large amount of resources [14]. Children simply may not have the memory resources required to generate a structural prediction while processing a *wh*-question. This account predicts that active gap filling may develop as memory resources grow.

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