Immature representation or immature deployment?
Modeling child pronoun resolution

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Background and Research Questions

Spanish subject pronouns are probabilistically associated with certain antecedents, depending on their (1a) FORM and the semantics of accompanying (1b) CONNECTIVES. They can also be categorically disambiguated by verbal number MORPHOLOGY (2).

Q1 Can children use these cues to interpret subject pronouns?

Q2 Are their non-adult-like interpretations due to immature **representation** or **deployment** of these cues?

Observed Input

54,757 utterances of naturalistic child-directed speech from Schmitt-Miller corpus (Forsythe et al. under review) hand-coded for reference to different antecedent types in the presence of each cue.

(1) *La maestra saluda a la niña …*
The teacher waves to the girl …

  a. *… y   { ø / ella } sale.*
     and {pro/she} leaves.

  b. *… { y después/porque } sale.*
     {and then/because} leaves.

(2) *La maestra saluda a las niñas y …*
The teacher waves to the girls and
… { sale / salen }.
   leave-3S/3P

Table 1: co-occurrence of antecedent types with cues in children's input

%subject ant.
(1,093/2,367)   ø
(64/291)   ella / ella

(29/54)   desp
(52/149)   porq

% singular ant.
(5,655/5,662)   SG
(9/1,336)   PL

Observed comprehension behavior (Forsythe 2019)

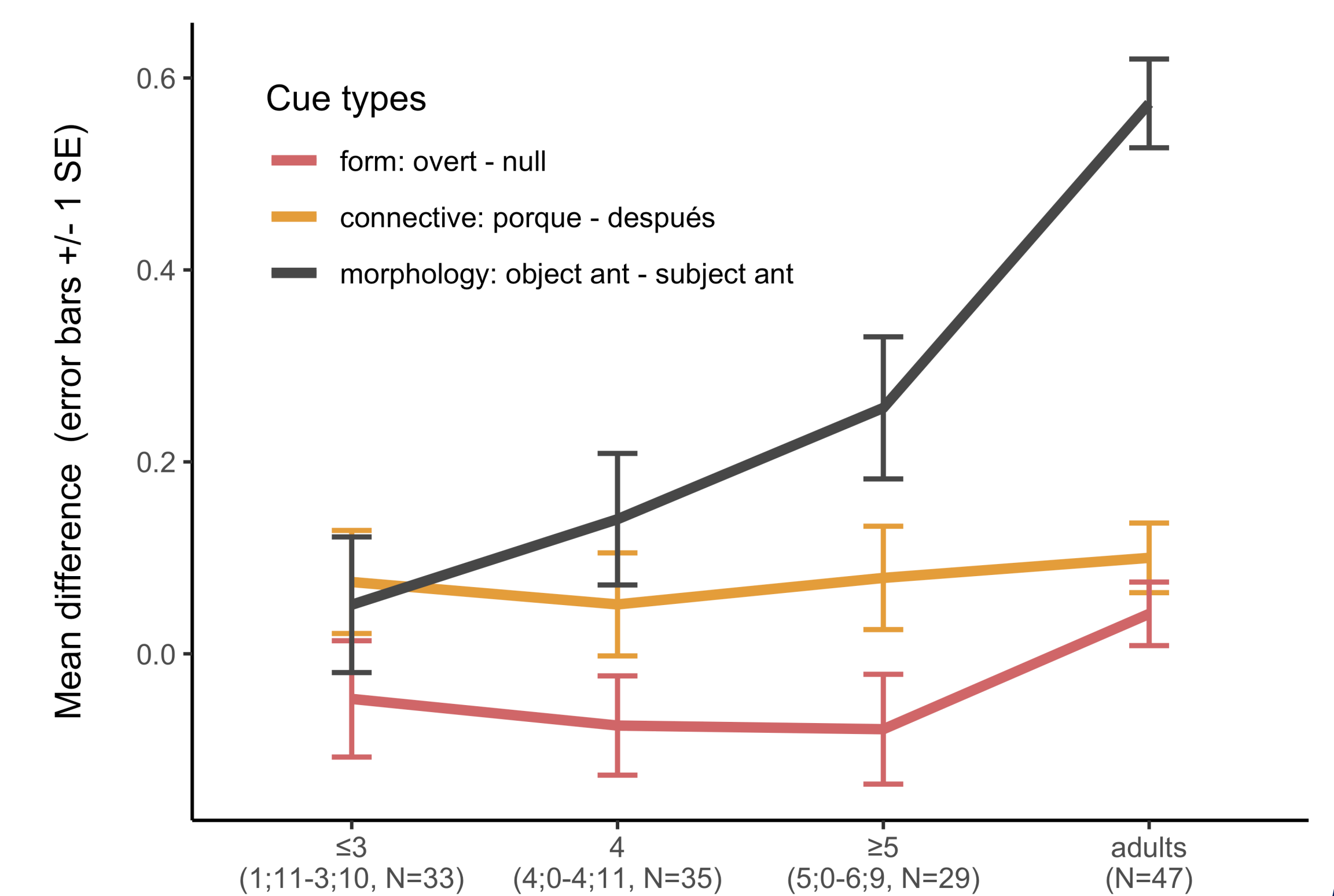**Fig. 1:** Example item, forced-choice picture selection (fully crossed)
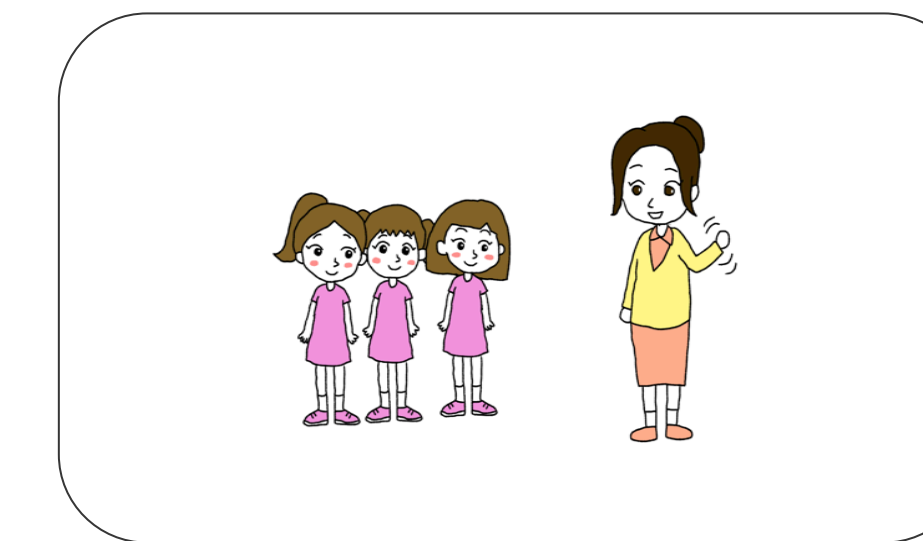
(3) *La maestra saluda a las niñas …*
The teacher waves to the girls …
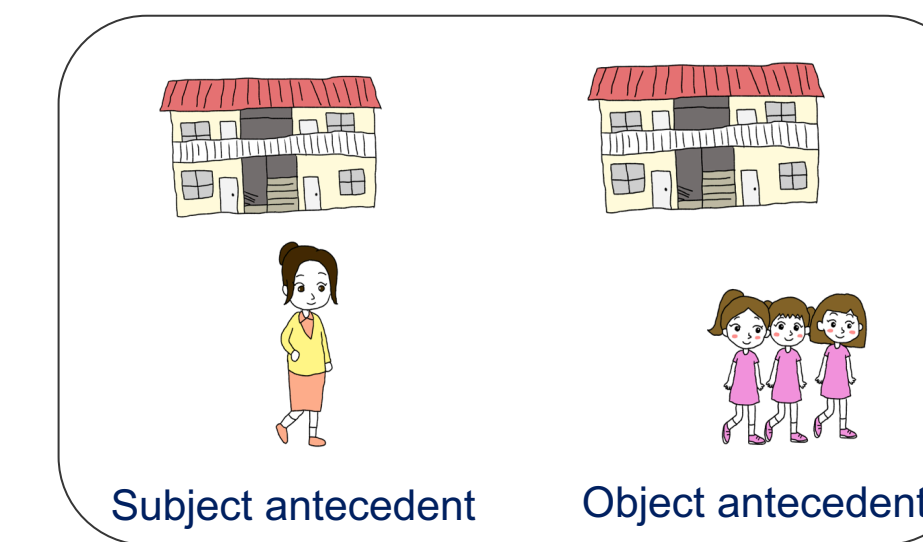
… y después ø salen.
… and then pro leave-3P

Subject antecedent   Object antecedent

Fig. 2: Proportion subject antecedent responses for object-favoring – subject-favoring cues

Cue types:
- form: overt - null
- connective: porque - después
- morphology: object ant - subject ant

Mean difference (error bars +/- 1 SE)

x-axis: ≤3 (1;11-3;10, N=33), 4 (4;0-4;11, N=35), ≥5 (5;0-6;9, N=29), adults (N=47)

H1 Noisy representation

Intuition: Immature cue representations **skew** the information children can extract from their input. **Likelihoods** will be noisier than an optimally modeled learner.

$$P(\alpha \mid f_{FOR}, f_{CON}, f_{MOR}) \propto \; exp(\log(\sigma_{FOR}\, P(f_{FOR} \mid \alpha)))$$
$$\cdot\; exp(\log(\sigma_{CON}\, P(f_{CON} \mid \alpha)))$$
$$\cdot\; exp(\log(\sigma_{MOR}\, P(f_{MOR} \mid \alpha)))$$
$$\cdot\; P(\alpha)$$

$P(f_{FOR} \mid \alpha)$ $P(f_{CON} \mid \alpha)$ $P(f_{MOR} \mid \alpha)$ → $P(\alpha \mid f_{FOR}, f_{CON}, f_{MOR})$ → $P(f_{FOR} \mid \alpha)$ $P(f_{CON} \mid \alpha)$ $P(f_{MOR} \mid \alpha)$

Fig. 3: Best-fitting noise parameters for noisy representation model

more noise

level of cue representation (σ_{CON}, σ_{MOR}, σ_{FOR}) vs. x-axis: 3, 4, 5, adu
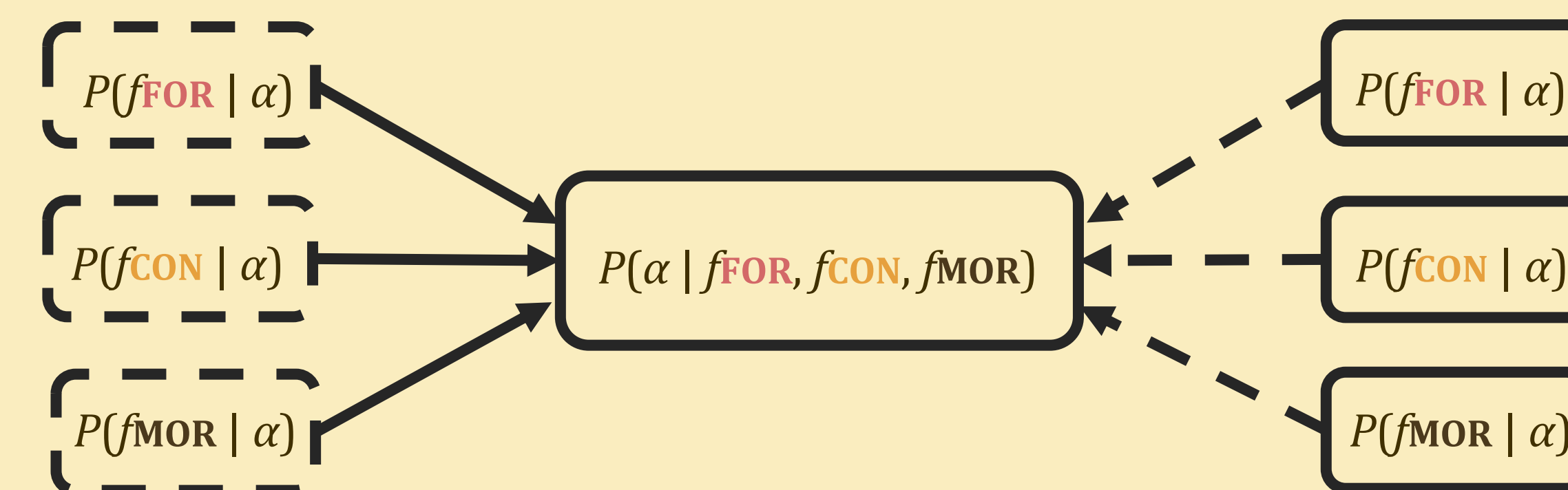
Table 2: Overall model fit to observed behavior

|	no noise	noisy representation	noisy deletion	
		MSE		
≤3	0.22	0.11	0.09	
4	0.15	0.11	0.09	
≥5	0.15	0.11	0.08	✓
adult	0.04	0.03	0.02	
		log likelihood		
≤3	-1774	-913	-835	
4	-1749	-956	-871	
≥5	-1264	-762	-668	✓
adult	-1201	-1113	-850	
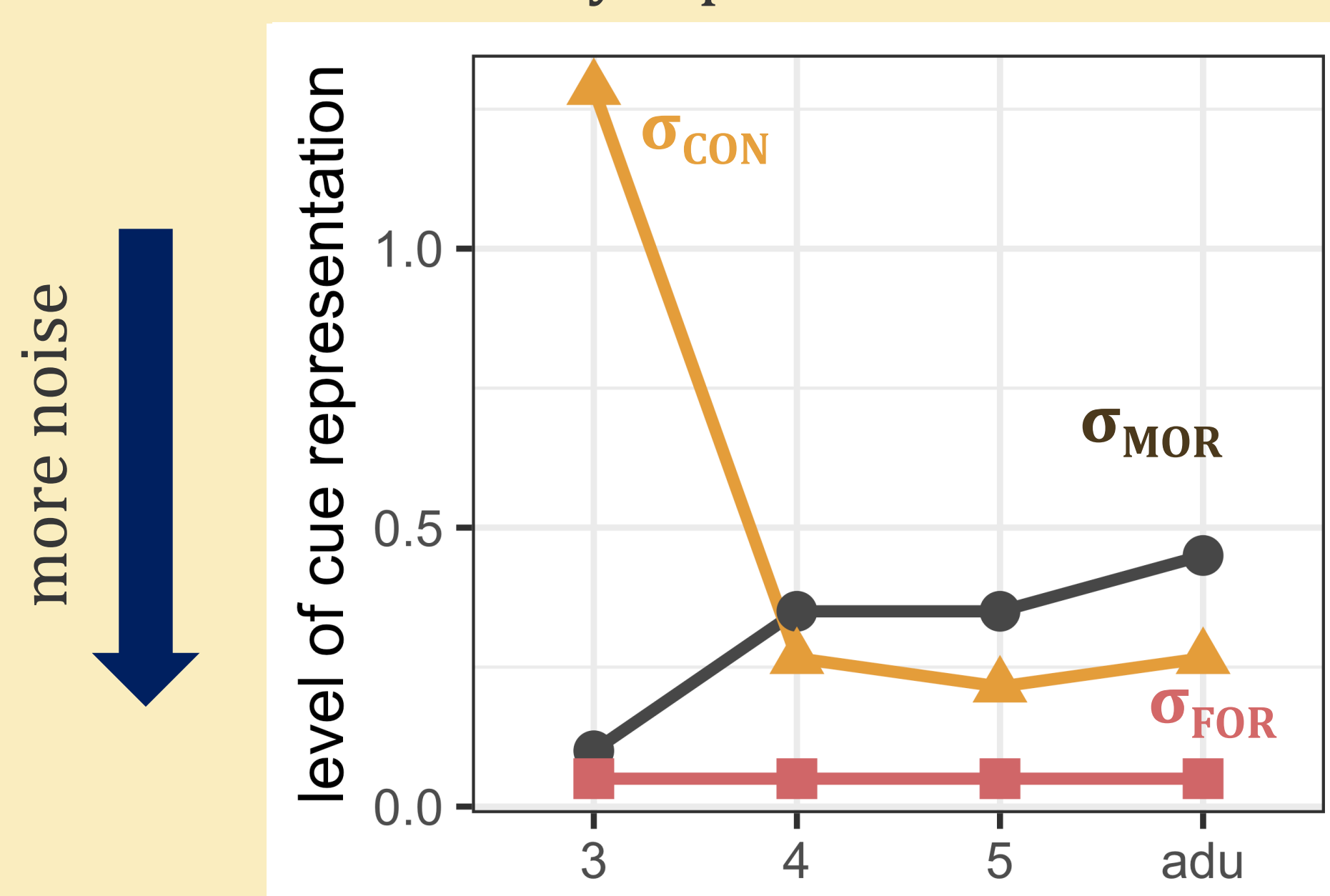
H2 Noisy deletion

Intuition: Children may **omit** some cues when calculating pronoun meaning. Optimal model is mixed with sub-optimal **cue deletion** models.

$$(\beta_{FOR})(\beta_{CON})(\beta_{MOR})\, P(\alpha \mid f_{FOR}, f_{CON}, f_{MOR}) +$$
$$(\beta_{FOR})(\beta_{CON})(1\text{-}\beta_{MOR})\, P(\alpha \mid f_{FOR}, f_{CON}) +$$
$$(\beta_{FOR})(1\text{-}\beta_{CON})(1\text{-}\beta_{MOR})\, P(\alpha \mid f_{FOR}) +$$
$$... +$$
$$(1\text{-}\beta_{FOR})(1\text{-}\beta_{CON})(1\text{-}\beta_{MOR})\, P(\alpha)$$

Fig. 4: Best-fitting noise parameters for noisy deletion model

level of cue inclusion (β_{CON}, β_{MOR}, β_{FOR}) vs. x-axis: 3, 4, 5, adu
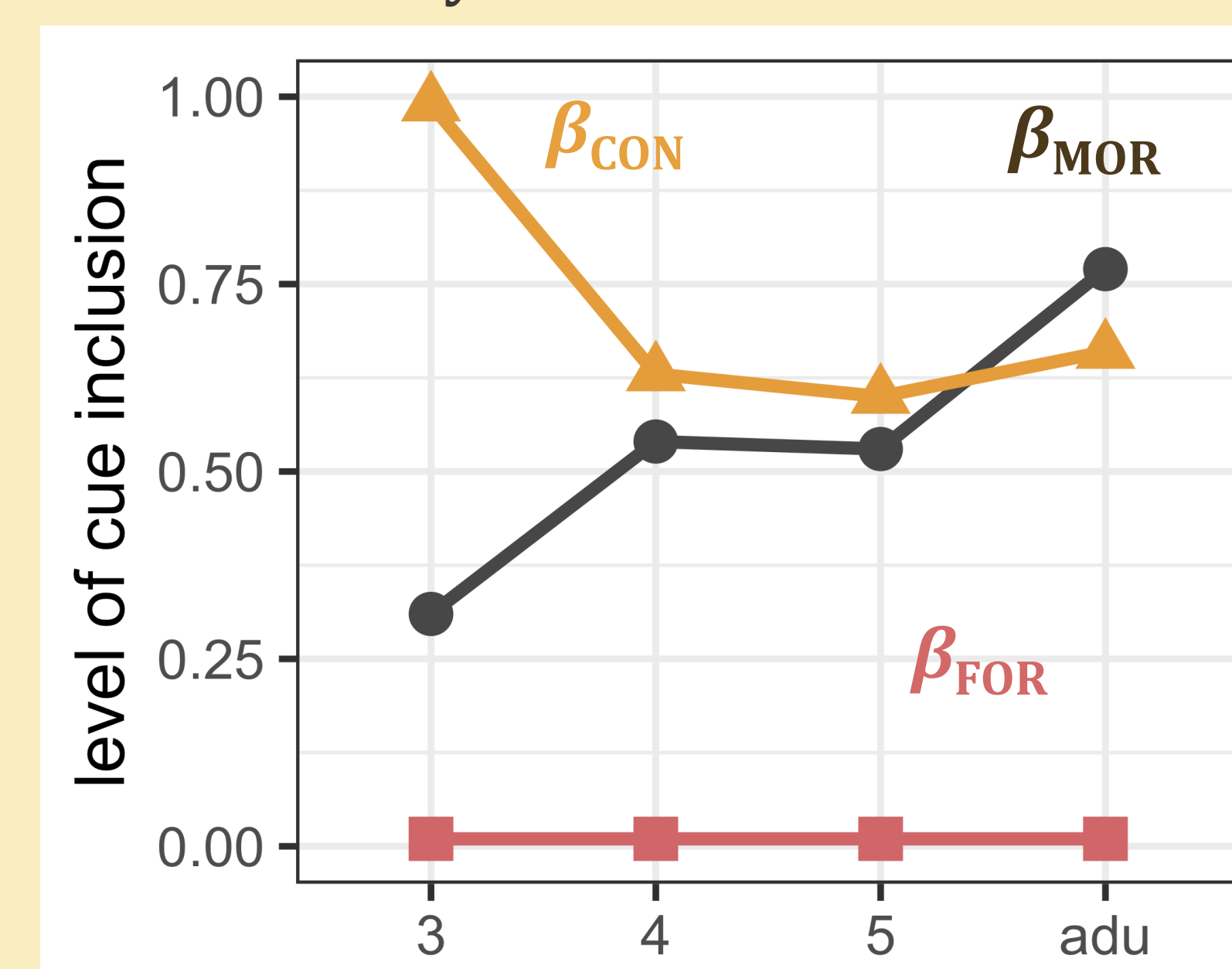
Summary and Discussion

A1 Children's use of Spanish verbal MORPHOLOGY is not fully adult-like, consistent with cross-linguistic findings (Pérez-Leroux 2005, Johnson et al. 2005, a.o.; but see Legendre et al. 2014).

A2 This behavior is more likely caused by **immature deployment** of otherwise adult-like representations, consistent with other findings on child pronoun comprehension (ex. Principle B Conroy et al. 2009, Spenader et al. 2009).