A statistical model of grammatical choices in children's productions of dative sentences

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Do children follow the same production pattern as adults?

Children's production seems to differ from adult speech.

It is an open question how to exactly characterize the differences.

Recent research has shown that syntactic alternation
in adult speech is influenced by multiple cues.

Do the same factors affect child production?

Case study: dative alternation

NP NP	I gonna show	**you**	something.
		RECIPIENT	THEME
NP PP	Show	it	**to her**.
		THEME	RECIPIENT

Our models measure the probability of selecting a NP PP construction.

Outline

1. **Modeling adult production of the dative alternation**

   Motivations behind this approach

   Logistic regression model

2. **Building a model for child production**

   CHILDES database

   Methodology and annotation

   Resultant model and discussion

3. **Model comparison between adult and child production**

Modeling adult production of the dative alternation

Variation in the dative construction has proven puzzling.

Various forces have been held responsible:

- lexical verb meaning [Gropen 89, Green 71]
- constructional differences [Goldberg 95]
- usage trends (e.g., phonological factors)

Detailed studies of actual usage show a more complicated picture.

Multiple factors affect dative construction choice

Statistical models allow one to investigate and predict factors influencing production.
[Arnold 00, Szmrecsányi 05, Becker 06, Bresnan et al. 07]

E.g., the influence of animacy and definiteness can be compared.

This was shown in the model of Bresnan et al. [Bresnan et al. 07]

Adult data comes from Switchboard

2360 dative observations from the 3 million word Switchboard collection of recorded telephone conversations.

Annotated for
- animacy
- givenness
- pronominality
- length
- person
- number
- verb and verb semantic class
- persistence
- . . .

This data set is publicly available for download as part of the languageR package.

Persistence

Persistence is a measure of production priming:
speakers reuse what they have just heard or just used.

Szmrecsányi found persistence to play a highly significant role in linguistic choice for different English alternations.
[Szmrecsányi 05]

Syntactic priming effects have also been reported in young children.
[Savage et al. 03, Huttenlocher et al. 04, Conwell and Demuth 07]

Logistic regression model

Logistic regression model controls simultaneously
for multiple factors giving a binary response.

$$\mathrm{P}(\text{Response} = \text{NP PP}|X) = \frac{1}{1+exp(-(\alpha+\beta_1 x_1+\beta_2 x_2+...))}$$

where X is the model matrix of independent variables $[x_1, x_2, \ldots]$
and βs are their coefficents.

Adult model shows harmonic alignment

Harmonic alignment of prominence scales with syntactic position:

shorter	>	longer
discourse given	>	not given
animate	>	inanimate
definite	>	indefinite
pronoun	>	non-pronoun

V NP NP	V recipient theme
V NP PP	V theme recipient

Building a model for child production

Previous studies of child acquisition of datives emphasized lexical verb meaning. [Pinker 89, Tomasello 01]

Given the adult model just shown, it's natural to question whether similar factors are in play for children.

We follow the approach of Bresnan et al. [Bresnan et al. 07] and build a logistic regression model.

Child data comes from CHILDES

We used a subset of the CHILDES database [MacWhinney 00]

7 children selected based on the amount of data available (both total utterances and utterances containing a dative construction)

538 utterances annotated for

- animacy
- givenness
- pronominality
- length
- persistence
- age
- MLU

Annotation: animacy

It is not clear how children perceive animacy.

We therefore used two different coding schemes for this factor:

- standardly assumed definition: humans and animals

- hypothetical over-generalization by children: the above plus toys

The results of the two coding schemes were not significantly different from each other.

Annotation: givenness

The theme/recipient is considered given
if it has been mentioned in the previous 10 speaker turns.

If so, we also coded the speaker of this previous mention
(child vs. adult).

Annotation: pronominality

definite pronoun	*it*
demonstrative pronoun	*that*
personal pronoun	*me*
reflexive pronoun	*myself*
personal pronoun followed by a lexical NP	*she gave* ***them all her children*** *a spanking.*

Annotation: length

The number of space-delimited words encodes the length.

Annotation: persistence

We coded for α persistence (exact match), whereby we located the first previous dative construction within a range of 10 speaker turns:

NP = previous NP NP in a dative construction

PP = previous NP PP in a dative construction

0 = no previous dative construction

We also took into account the distance (in number of clauses), as well as the speaker uttering the previous construction (adult vs. child).

Annotation: MLU

Mean Length Utterance measured in morphemes,
as computed by the CLAN program.

Logistic regression model for child production

Probability {Response = NP PP}	*given*	animacy
		givenness
		pronominality
		length
		persistence
		age
		MLU

Following standard methods, we use backward elimination to extract the most significant factors, i.e., those which account for the greatest amount of the variation in the data without overfitting the model.

Logistic regression model

$$\mathrm{P}(\text{Response} = \text{NP PP}|X) = \frac{1}{1+exp(-(\alpha+\beta_1 x_1+\beta_2 x_2+...))}$$

where α is
− 0.27

and $\beta_i x_i$ are

+ 2.36 {theme type = pronoun}
− 1.59 {recipient type = pronoun}
− 0.72 {theme length}
− 1.45 {previous dative = NP}
+ 1.81 {previous dative = PP}

Significant factors for child production

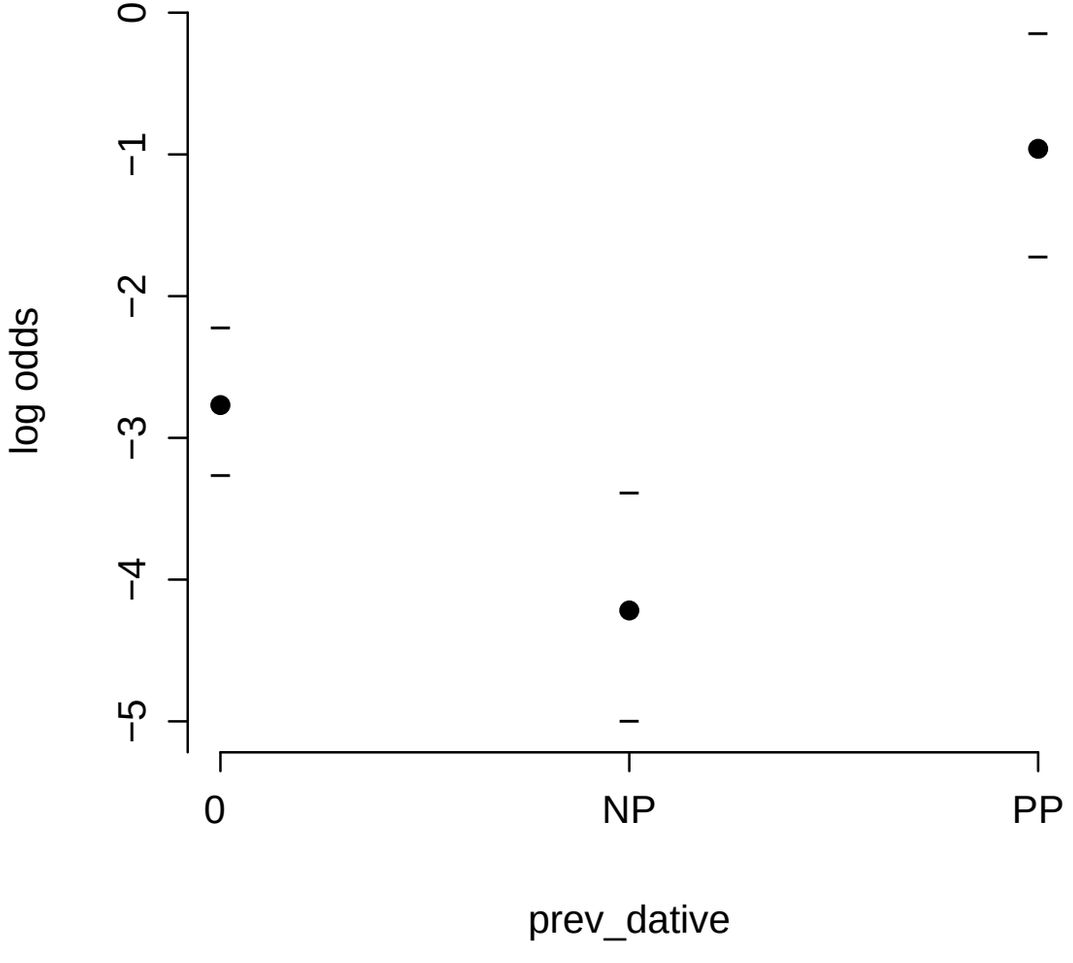
The quality of the obtained model is high:

C $= 90.9$
Nagelkerke $R^2 = 56.9$ (56.2 with bootstrap validation)

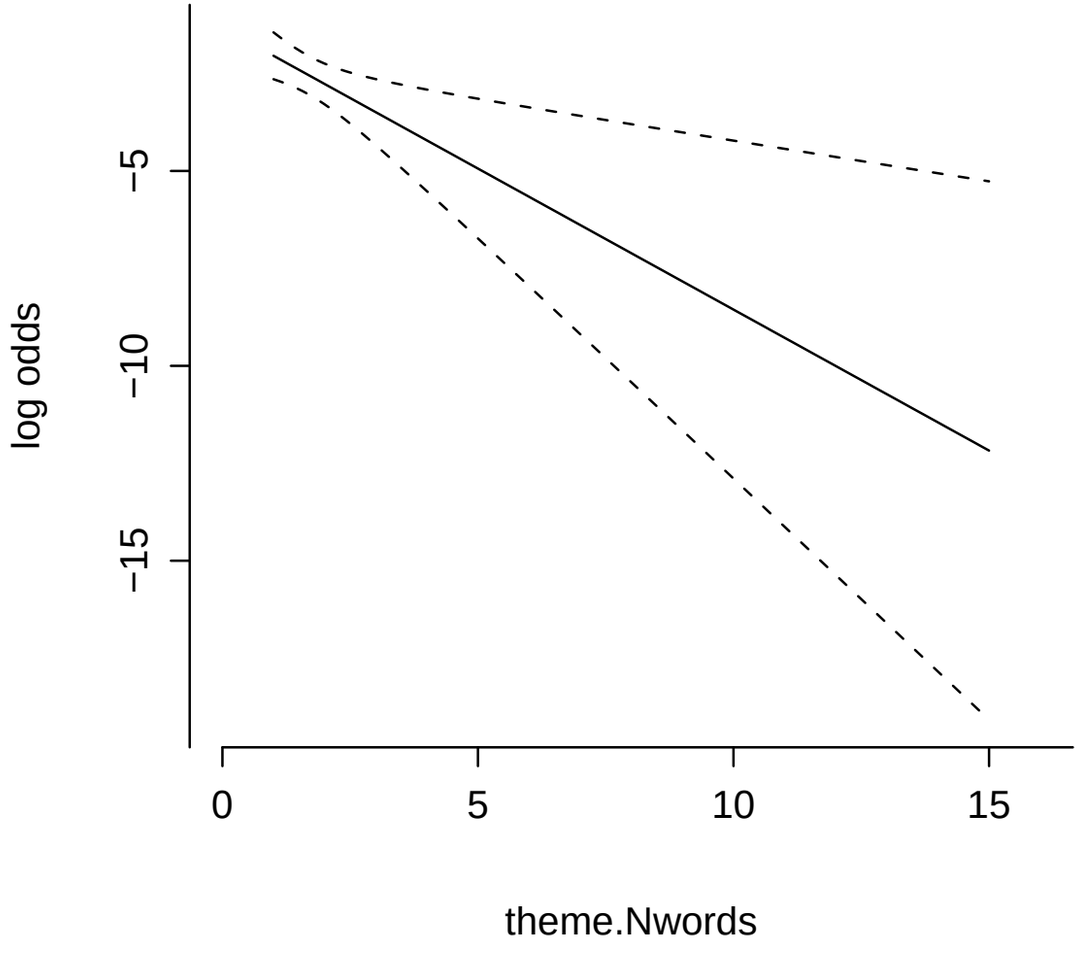
4 factors are independently significant (no collinearity, $p < .05$):

Factor	Odds	P-Value
theme type=pronoun	10.57	0.0000
recipient type=pronoun	0.20	0.0000
theme length	0.49	0.0061
previous dative=NP	0.24	0.0002
previous dative=PP	6.10	0.0000

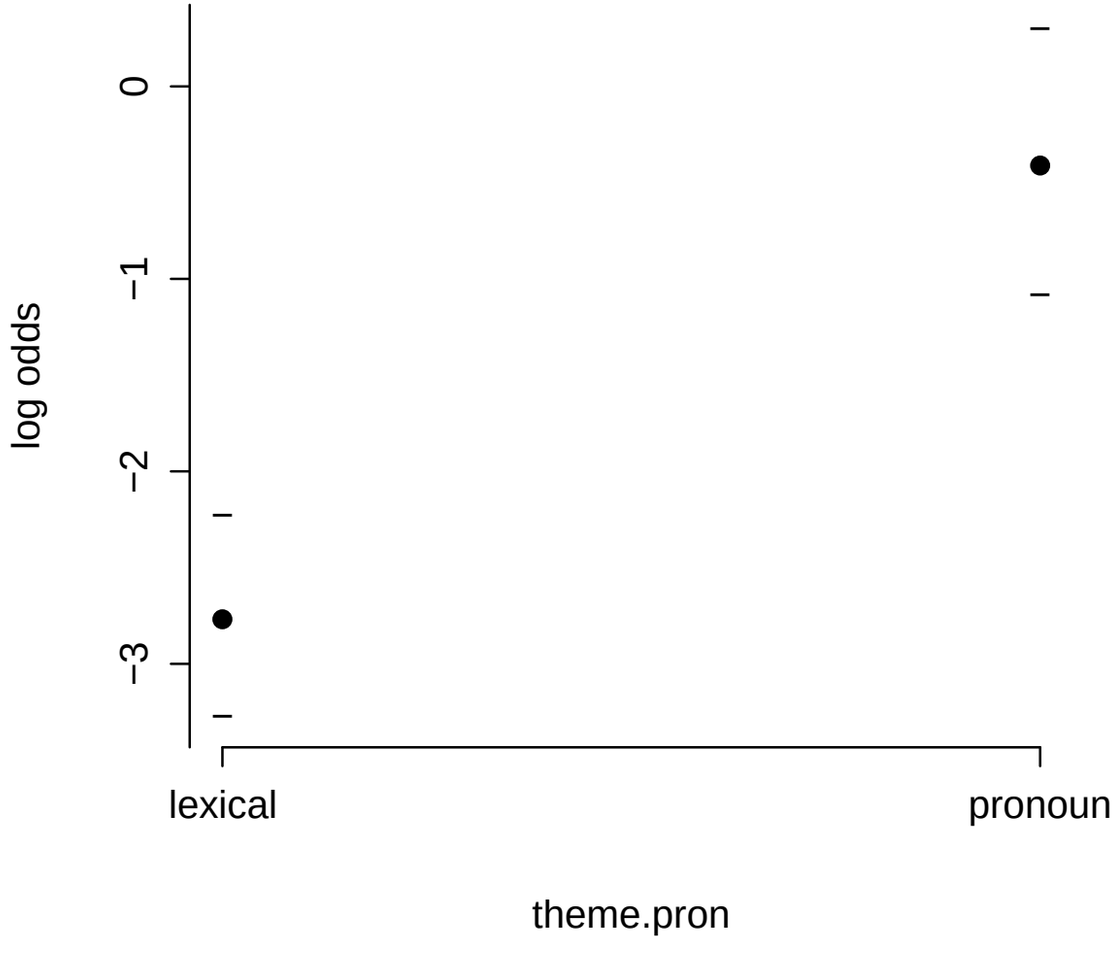
Previous construction tends to persist



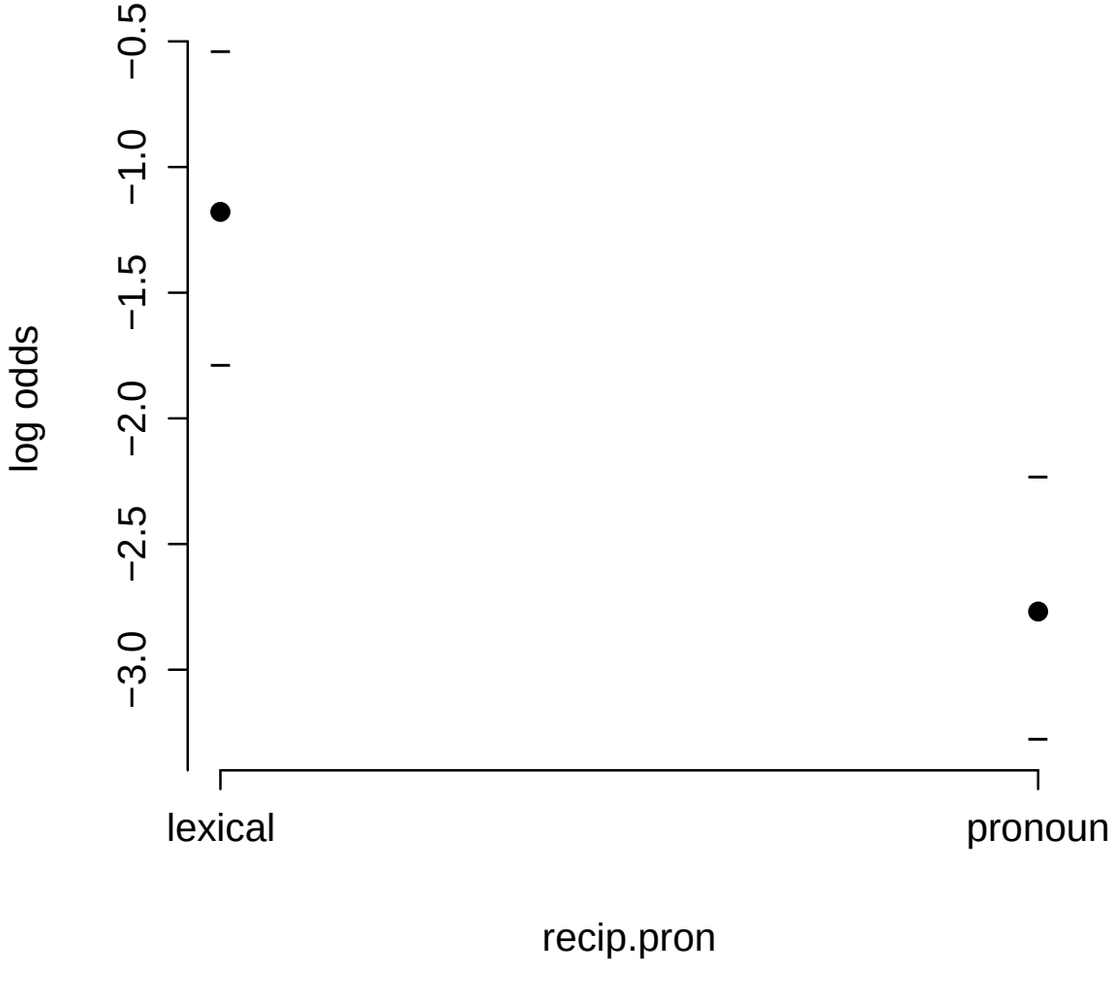
Decrease in theme length favors NP PP



Pronominal theme favors NP PP



Lexical recipient favors NP PP



Child data shows harmonic alignment

As in the adult data, the child data show a qualitative picture of a quantitative harmonic alignment.

shorter	>	longer
pronoun	>	non-pronoun

V NP NP	V recipient theme
V NP PP	V theme recipient

There is no speaker effect

Given that the children vary a lot in their individual developmental trajectories [Clark 03], we must control for whether the speaker is a significant factor, which data pooling has obscured.

Using "child" as a random effect in a mixed effect model didn't lead to a significant result:

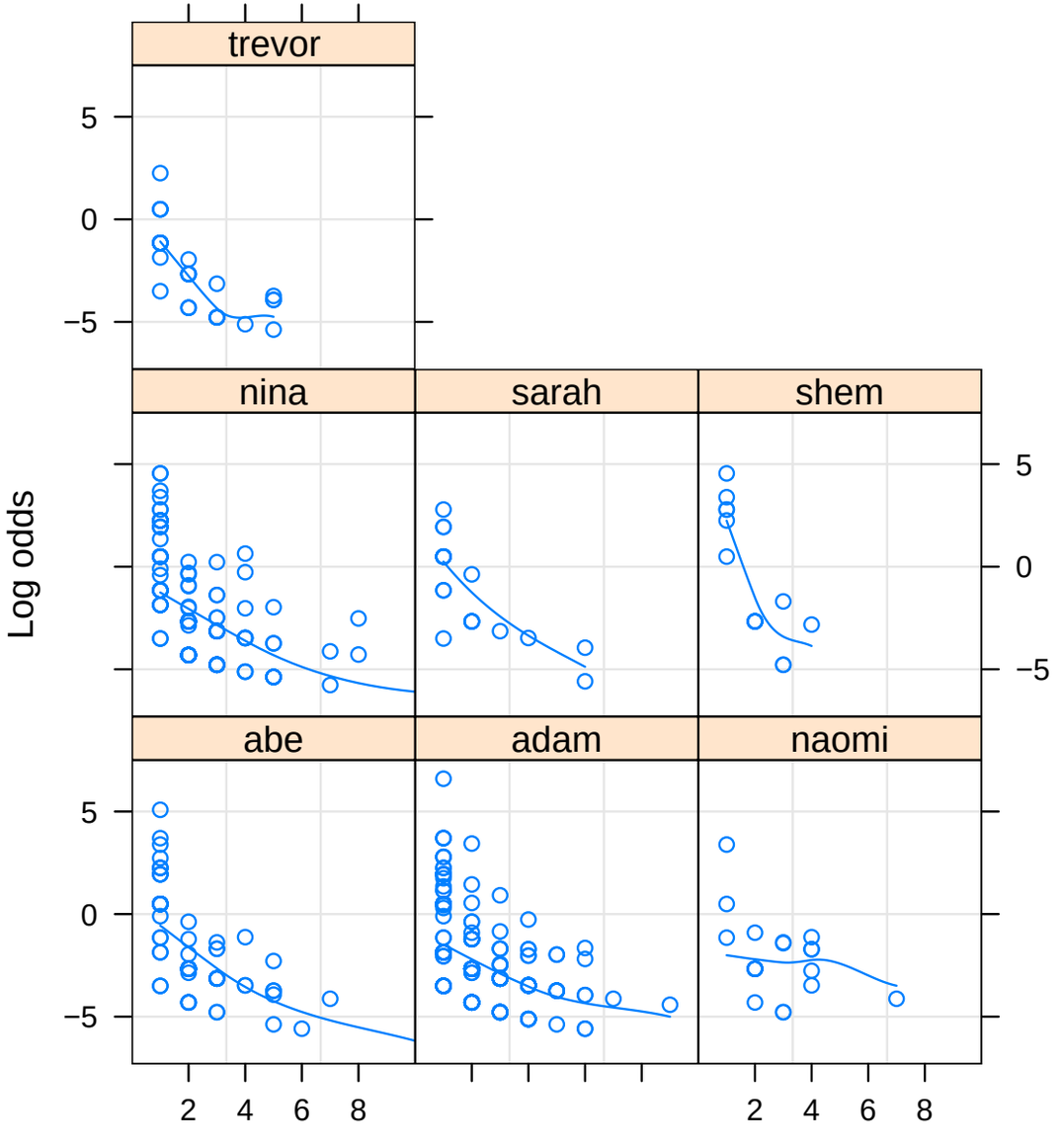
surprisingly the global trends hold locally.

There is no speaker effect

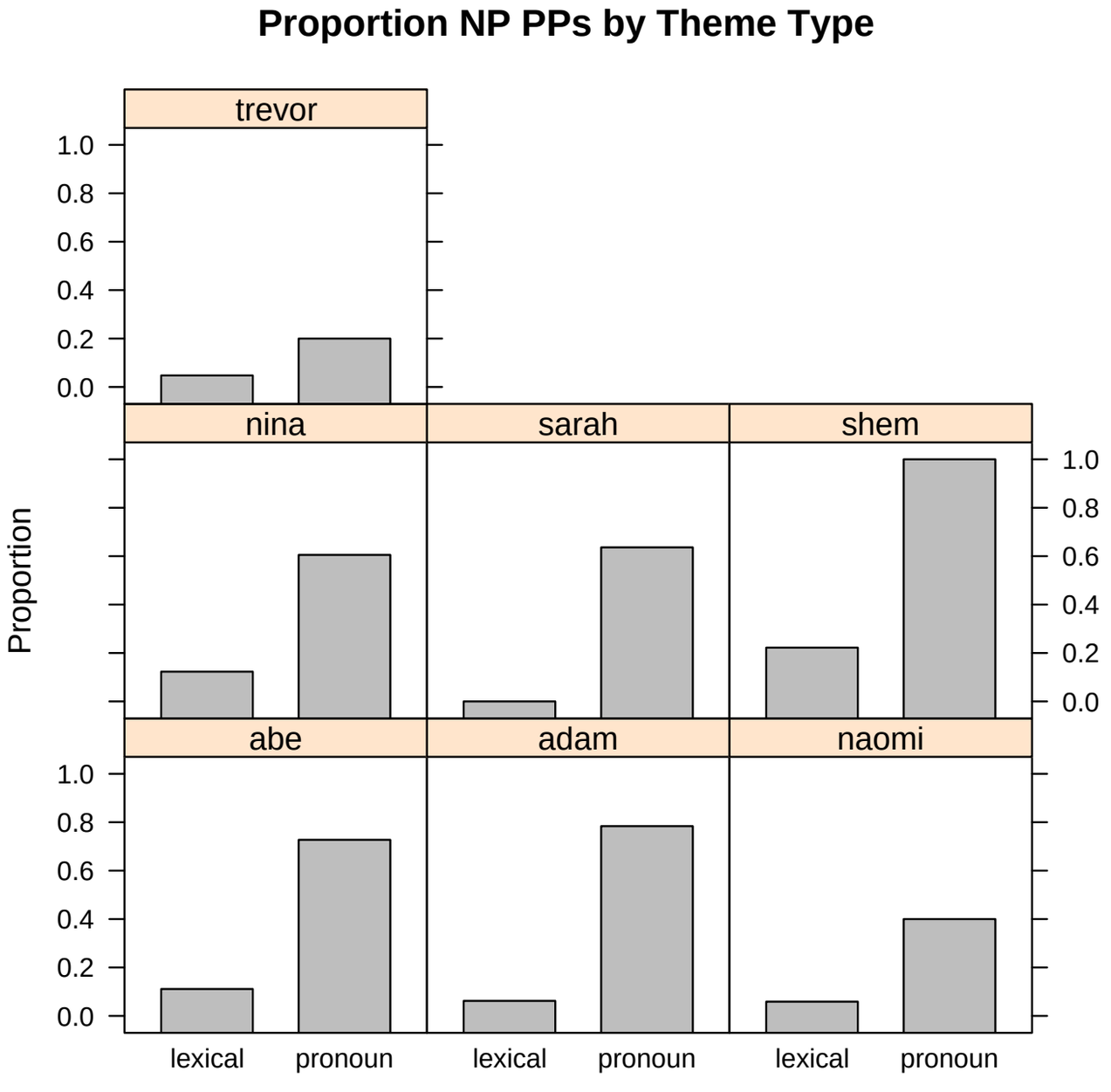
Coefficients of both models are very similar:

Factor	Fixed effect model coefficients	Mixed effect model coefficients
theme type=pronoun	+ 2.36	+ 2.35
recipient type=pronoun	− 1.59	− 1.60
theme length	− 0.72	− 0.73
previous dative=NP	− 1.45	− 1.46
previous dative=PP	+ 1.81	+ 1.80

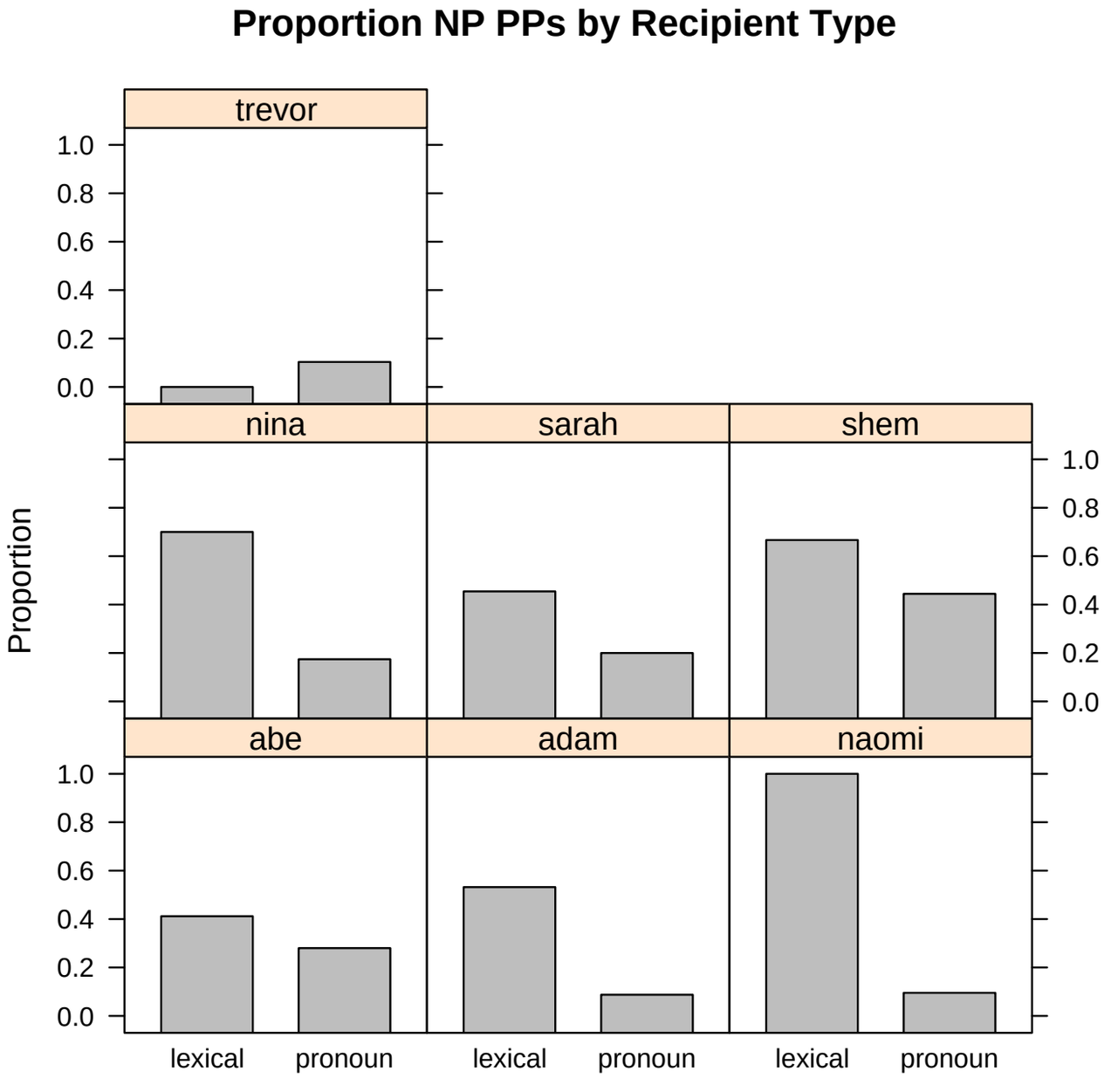
Length of theme effect by child



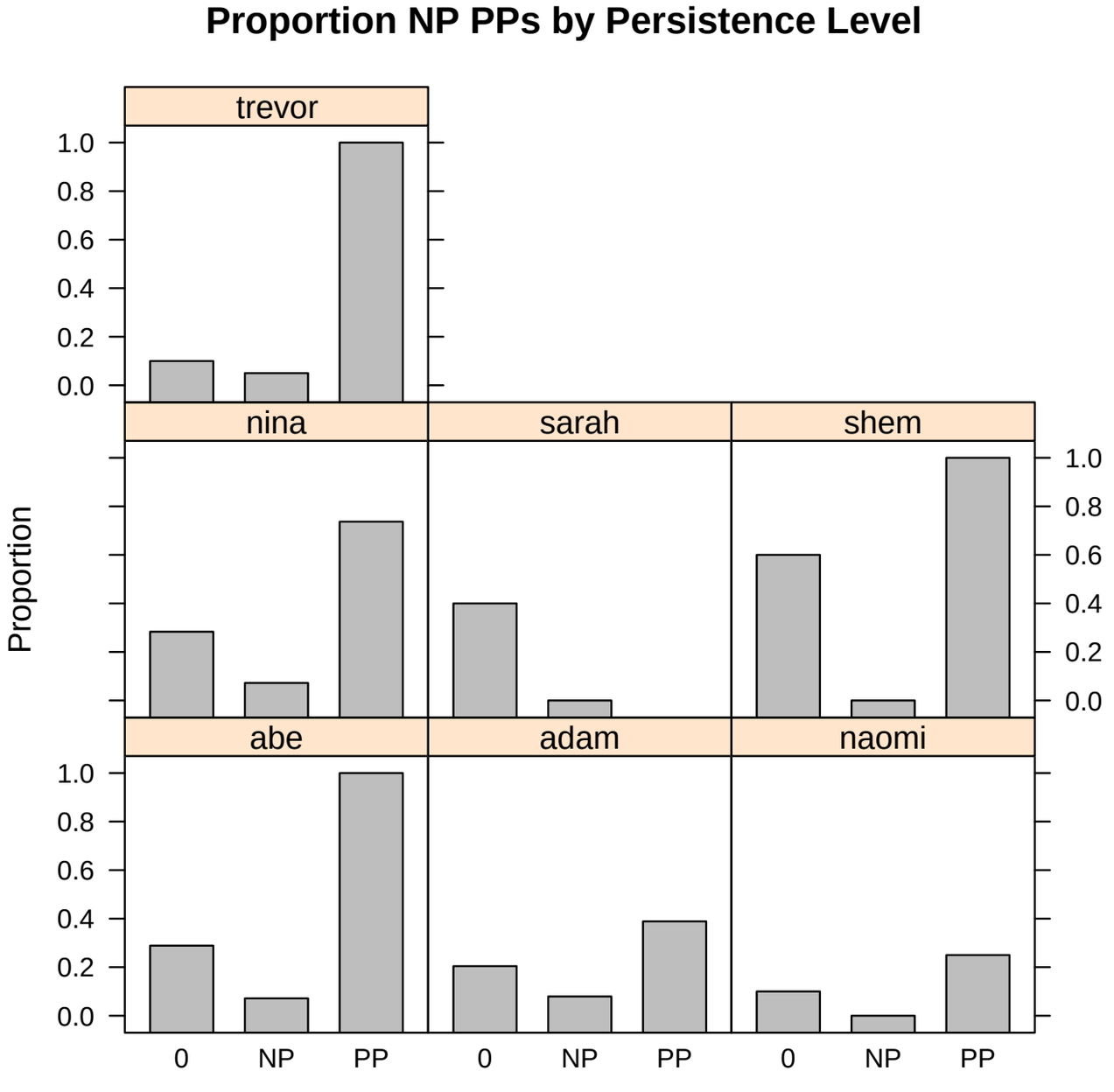
Theme type effect by child



Recipient type effect by child



Persistence effect by child



Multiple factors affect child production

The overall picture of Bresnan et al. [Bresnan et al. 07] is much the same in child production of dative sentences:
construction choice is governed by multiple factors,
which align harmonically.

Differences from the adult model

Number of factors	Overall there were fewer significant factors in the child model.
Animacy	Despite our expectations, animacy was not found to be a significant factor in the child model.

The two models suggest that there might be a difference between children and adults in the relation of animacy to construction choice.

Differences from the adult model

The factors differ in magnitude:

CHILD		ADULT	
factor	AIC	factor	AIC
		verb	- 1.95
		previous dative	0.12
		recipient animacy	0.45
theme length	5.53	theme length	4.30
		recipient length	7.76
		theme animacy	12.79
recipient type	28.65	recipient type	26.77
previous dative	57.49		
theme type	114.75	theme type	46.57

Differences from the adult model

We cannot infer such differences directly from two independent models.

To fully assess similarities and differences between children and adults, one must analyze these factors across the data in a conjoined model.

Model comparison between adults and children

We limited the adult model to the verbs *give* and *show*.
This gives 611 data points,
comparable to the 538 occurrences for the child data.

We refitted the adult model to this restricted data set, and found no differences in main effects, e.g., animacy remains significant.

We re-coded persistence in the adult data to approximate the 10 speaker turn range used in the child data.

Model comparison between adults and children

The conjoined model attains high quality

The conjoined model demonstrates that the following factors remain significant across data sets:

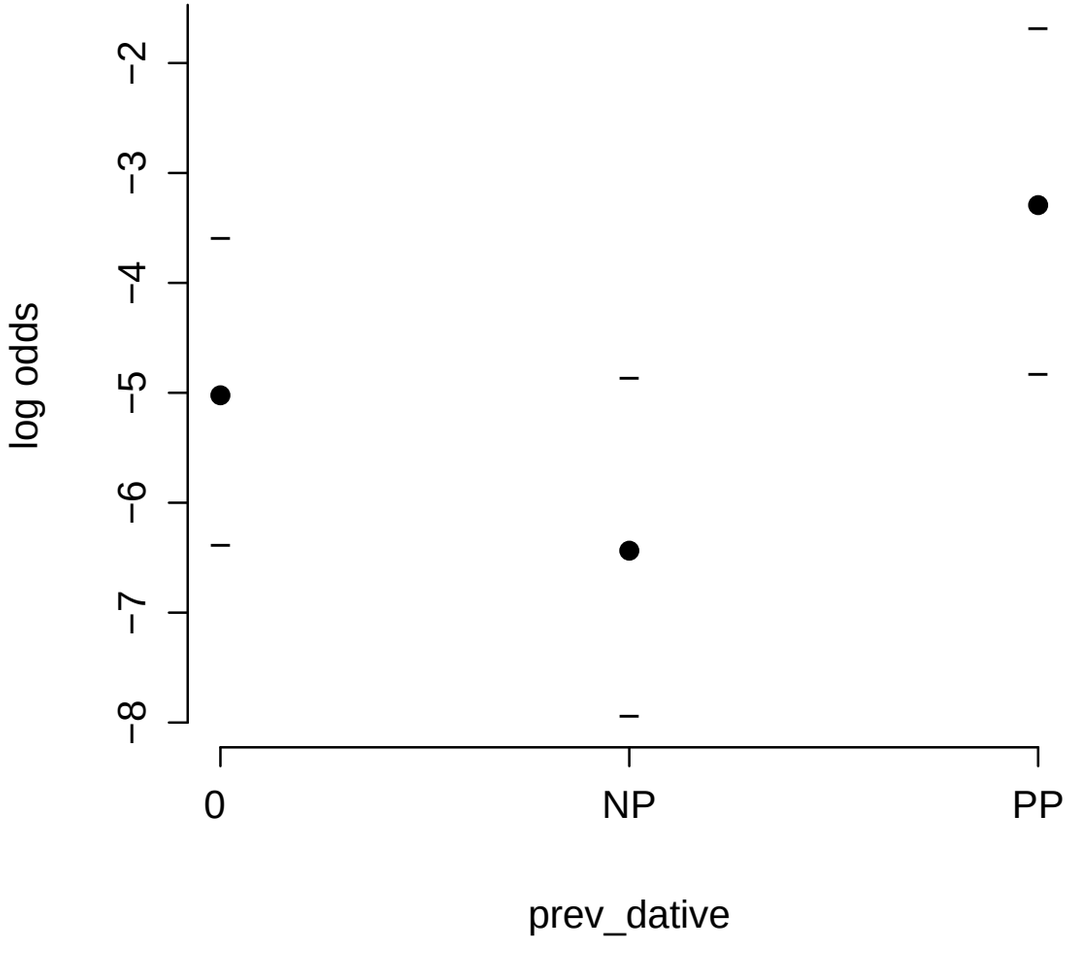
C $= 95.7$

Nagelkerke $R^2 = 70.3$ (69.2 with bootstrap validation)

Factor	Odds	P-Value	
intercept	0.284	0.0824	
recipient type=pronoun	0.021	0.0000	
theme type=pronoun	1536.0	0.0000	
recipient length	2.6	0.0021	Main effects
theme length	0.646	0.0008	
previous dative=NP	0.240	0.0000	
previous dative=PP	5.5	0.0000	
group=child $*$ recipient type=pronoun	11.0	0.0073	Interactions
group=child $*$ theme type=pronoun	0.008	0.0000	

Model comparison between adults and children

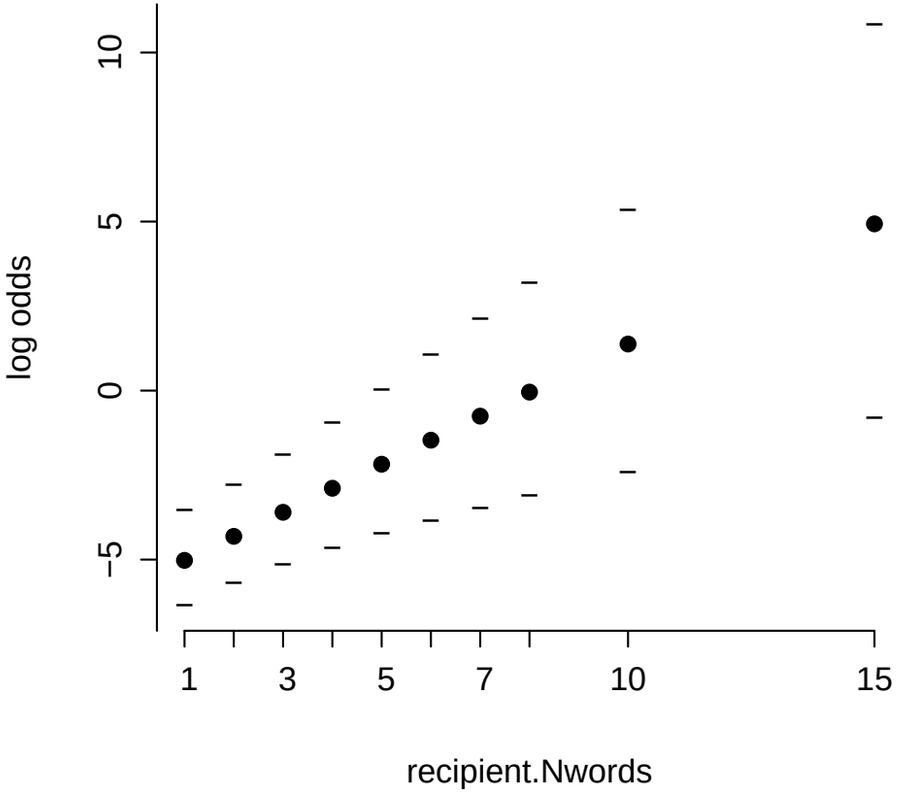
Persistence plays a role



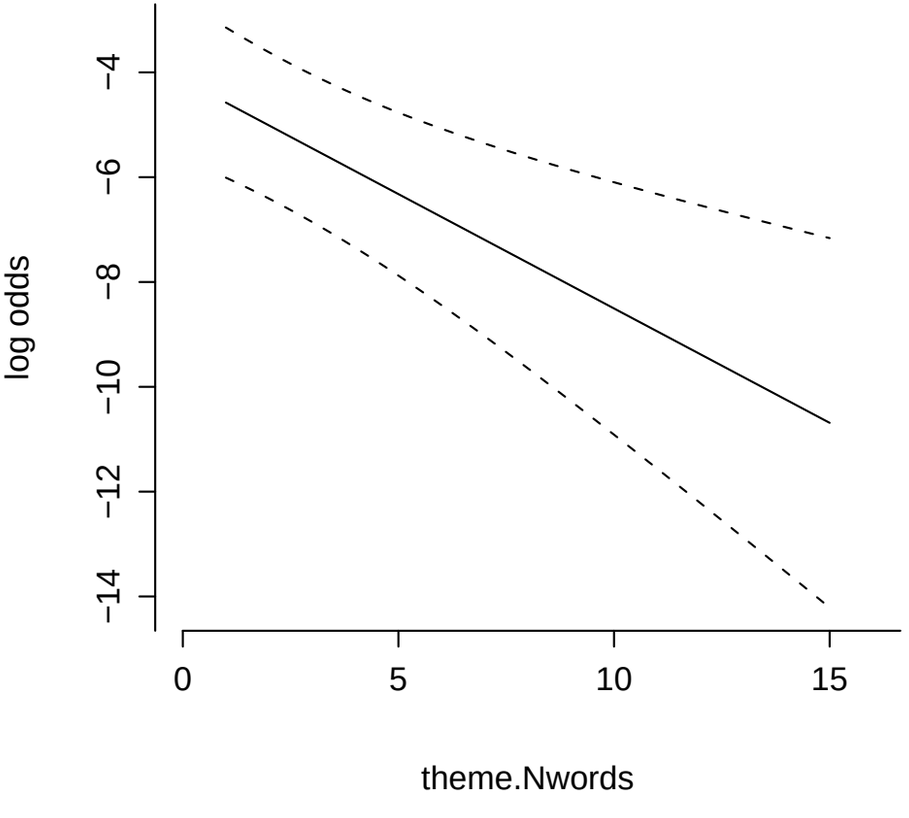
Model comparison between adults and children

Length of recipient and theme matters

Increase in recipient length favors NP PP



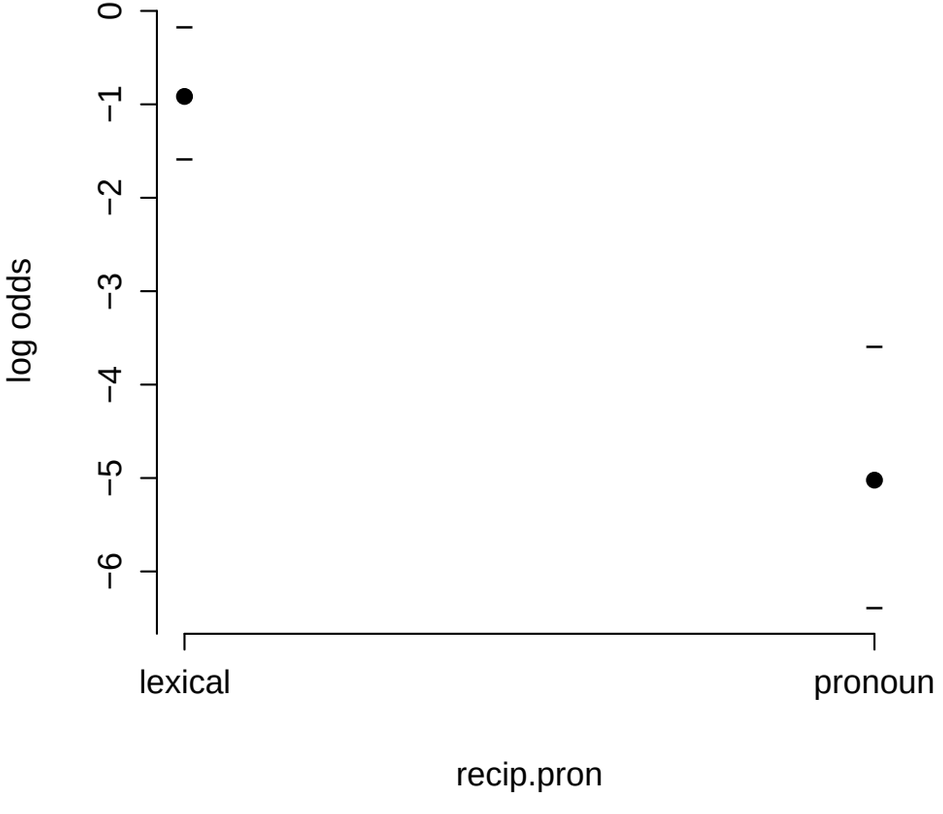
Decrease in theme length favors NP PP



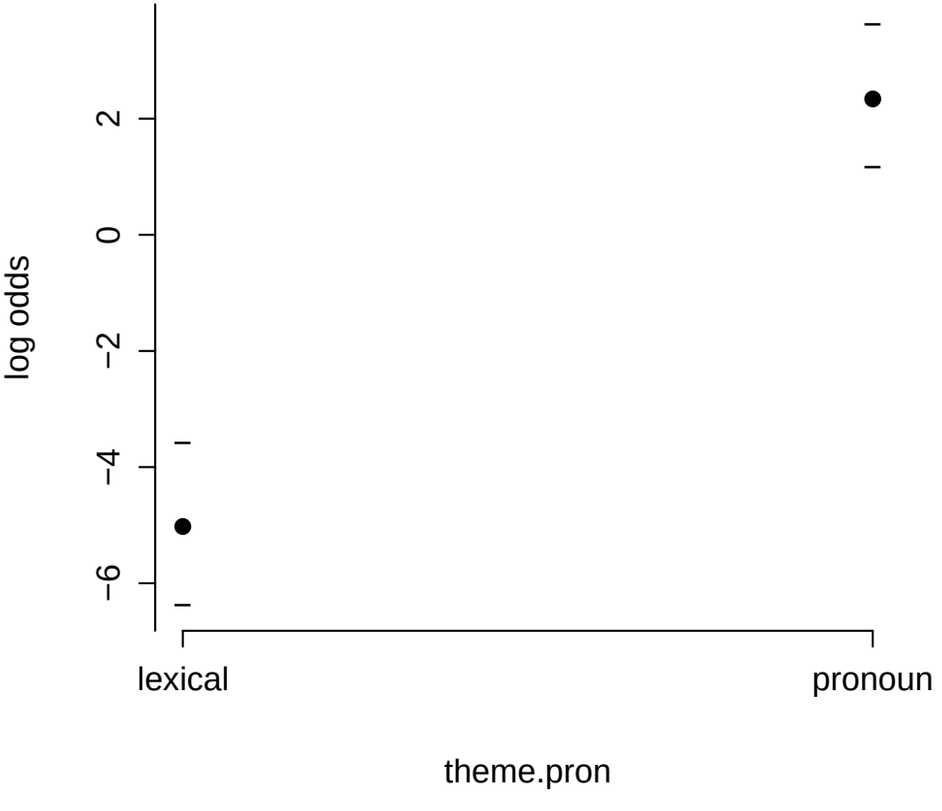
Model comparison between adults and children

Type of recipient and theme

Lexical recipient favors NP PP



Pronominal theme favors NP PP



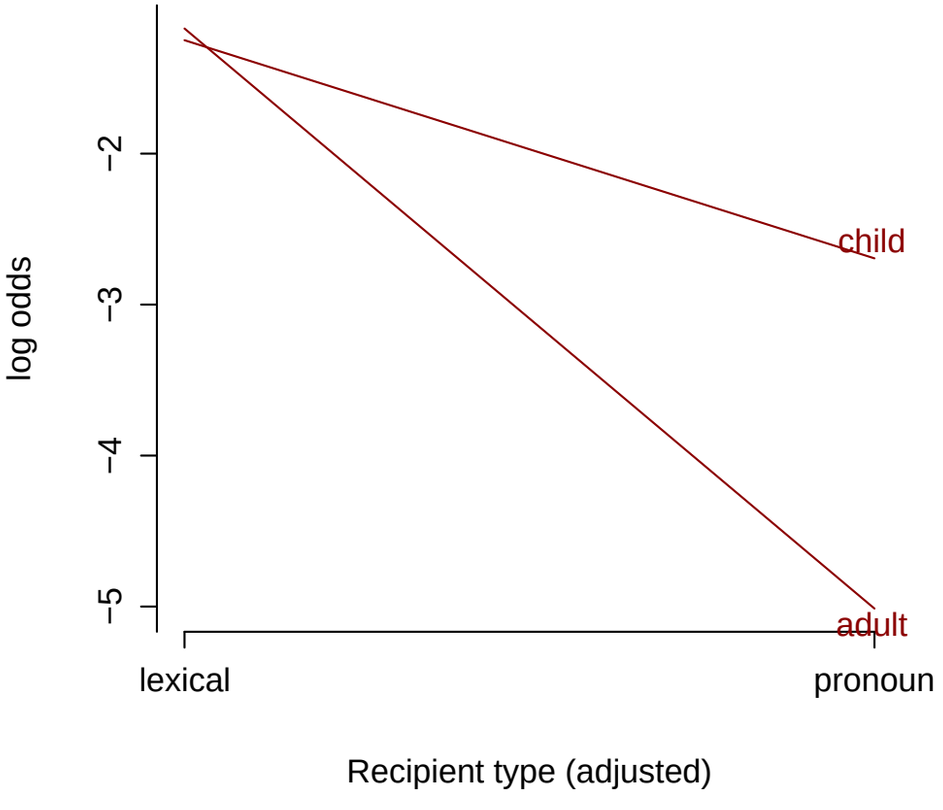
Harmonic alignment is a significant main effect across both groups

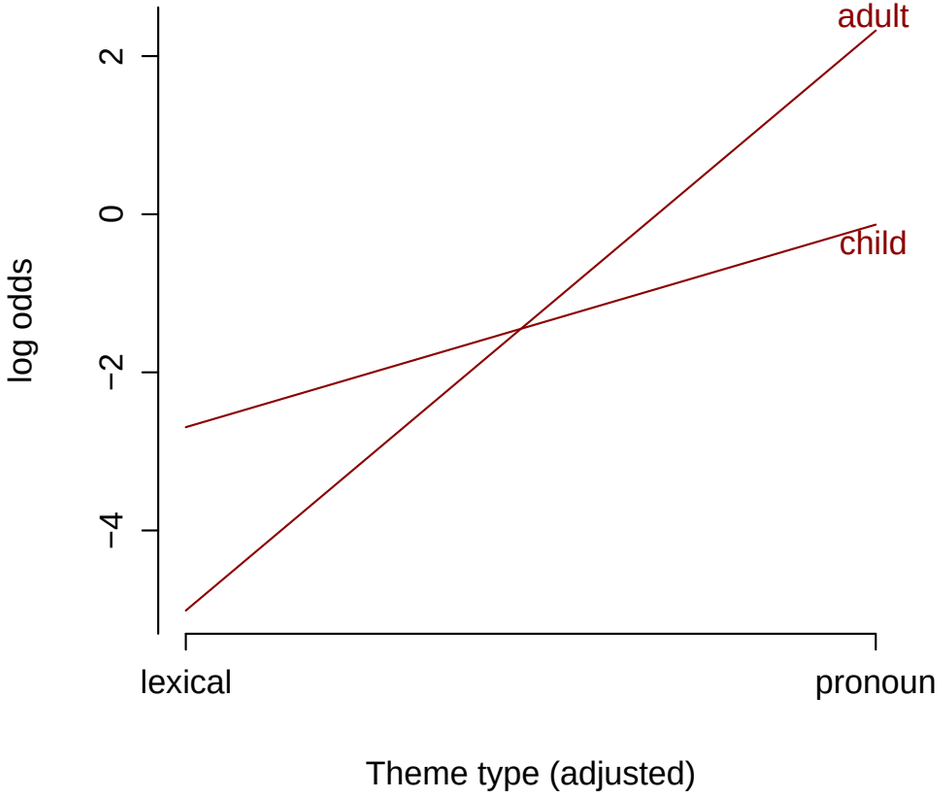
The children's and the adults' construction choices show a consistent statistical pattern of harmonic alignment.

All of the measured harmonic alignment effects
(except the animacy effect)
are significant across both groups.

Interaction: recipient and theme types

For adults the type of NPs has greater influence on the production choice.





Interaction: variation by degree

The interaction effects show that the two groups
differ in their sensitivity to the shared factors.

Child and adult productions demonstrate the same general behavior,
which corresponds to a shared harmonic alignment pattern.

The differences in the interactions are a matter of degree,
not direction.

Conclusion

We have demonstrated the feasibility of comparing child and adult speech, and shown that statistical modeling techniques can yield insight into the factors at play in children's speech production.

Given the size of the corpus, our results are promising rather than definitive. Further research may shed light upon why the differences between these patterns of production were observed (input children receive, resource limitations).

The production choices made by children and adults are neither identical nor radically different: a core set of factors are shared.

There are no collinearities between co-variates

VIF measures (the closer to 1 the better)

theme type = pronoun	1.30
recipient type = pronoun	1.02
previous dative = NP	1.06
previous dative = PP	1.08
theme length	1.27