A statistical model of the grammatical choices in child production of dative sentences

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Abstract

Focusing on children's production of the dative alternation in English, we examine whether children's choices are influenced by the same factors that influence adults' choices, and whether, like adults, they are sensitive to multiple factors simultaneously. We do so by using mixed-effect regression models to analyze child and child-directed datives extracted from the CHILDES corpus. Such models allow us to investigate the collective and independent effects of multiple factors simultaneously. The results show that children's choices are influenced by multiple factors (length of theme and recipient, nominal expression type of both, syntactic persistence) and pattern similarly to child-directed speech. Our findings demonstrate parallels between child and adult speech, consistent with recent acquisition research suggesting there is continuity between child and adult grammars. Furthermore, they highlight the utility of analyzing children's speech from a multi-variable perspective, and portray a learner who is sensitive to the multiple cues present in her input.

1   Introduction

One of the central questions in child language acquisition is the degree of continuity between child and adult language, both in the linguistic representations that children and adults draw on (e.g., how abstract children's early knowledge is (Tomasello 1992 vs. Wexler 1999)), and in the processing mechanisms that they employ (e.g., how similar are the processing preferences exhibited by children and adults (Trueswell & Gleitman 2007)[1]. On a theoretical level, the question of continuity has implications for the kind of

language learning model we adopt, for what we think children have to learn, and how they go about doing it. On an empirical level, the question has an impact on the kinds of questions we ask, and the explanations we use to explain children's language use. Specifically, it influences how likely we are to look for parallels in how children and adults use language, and how useful we deem adult psycholinguistic findings to the study of child language development.

In this paper, we focus on the factors that guide children's syntactic production to ask two related questions. The first is whether children's syntactic choices are influenced by the same factors that influence adults' choices. If so, this would argue for continuity in processing. The second is whether children's syntactic choices, like those of adults, are influenced by multiple factors simultaneously, including semantic and pragmatic ones. Such findings would indicate that young speakers are sensitive to complex distributional patterns and would call for learning models that can capture and predict how those multiple variables feed into the acquisition process. From the perspective of the question of continuity posed in the previous paragraph, we want to investigate the theoretical and empirical utility of drawing on adult psycholinguistic models to account for children's syntactic choices.

There is extensive evidence that children are sensitive to different types of information present in their input. For instance, semantic information, such as animacy and definiteness, influences production and comprehension even in the early stages of language development (see i.a., Drenhaus & Féry 2008, Snedeker & Trueswell 2004, Trueswell et al. 2008). Frequency of verbs and constructions also plays a role in shaping children's early productions (Tomasello 2003). To cite just one example, children produce constructions earlier with verbs that appear in them more frequently (Tomasello & Brooks 1998, Lieven et al. 2003). These findings often draw on experimental manipulations or corpus studies where the focus is on one variable (animacy, frequency, etc.). They demonstrate the range of factors that children are sensitive to, but do not investigate how and whether the different factors interact.

Little work to date has considered how multiple variables shape child production. Looking at adult psycholinguistic findings, there is reason to believe that taking a multi-variable perspective on child production may be advantageous. Current studies on adult production have been investigating exactly this question, revealing that adult production is sensitive to multiple variables, including both discourse and grammatical variables (see representative studies by Szmrecsanyi 2005, Jaeger 2006, Bresnan et al. 2007, Hinrichs & Szmrecsanyi 2007). These studies employ statistical models, as well as rich corpus data, to examine the effect of multiple variables simultaneously, yielding insight into the collective effect of different kinds of information as well as the magnitude of each variables independent contribution.

In the current paper, we ask whether child production can be modeled using similar methods. Applying such models and methods to child production will allow us to ask whether children are influenced by the same, multiple factors that affect adult production. It will be the first study to report a multi-variable model of child production. Specifically, we focus on children's production of the dative alternation. The study of syntactic alternations (e.g., the dative alternation, the locative alternation) provides a fruitful domain to investigate the multiple variables that influence production. Alternations allow us to explore the kinds of variables that lead speakers to choose between multiple possible syntactic forms which express roughly the same message. The English dative alternation provides an especially fruitful area of investigation because of its previous study in both children and adults. The dative alternation refers to the choice between a prepositional dative construction (NP PP) illustrated in 1a and a double object

construction (NP NP) illustrated in 1b.

  1a.   I showed some tricks to my Daddy.   (NP PP)

  1b.   I showed my Daddy some tricks.   (NP NP)

  The dative construction has received considerable attention in adult production studies as well as in acquisition research. Corpus studies of adult English have found that grammatical and discourse properties of the recipient and theme have a quantitative influence on dative syntax (i.a., Thompson 1990, Collins 1995, Snyder 2003, Gries 2003). More recently, Bresnan et al. (2007) proposed a model which shows that the effects of discourse accessibility, animacy, definiteness, pronominality, and syntactic weight are each significant variables influencing adult dative construction choice.

  The dative alternation is also suitable for exploring child production: it is frequently used by children and robustly attested in child-directed speech (Gropen et al. 1989, Snyder & Stromswold 1997, Campbell & Tomasello 2001). Yet, it has not been studied in a multi-variable perspective. Research has often focused on questions such as the nature or the productivity of the alternation (Snyder & Stromswold 1997, Campbell & Tomasello 2001, Conwell & Demuth 2007). Much research has also focused on children's over-generalization errors: producing an alternation with verbs which do not standardly alternate in adult production (Bowerman 1996, Gropen et al. 1989). While these errors are a rich source of evidence about development, here we will be concerned with variables that govern child production of core alternating verbs (e.g., *give*, *show*).

  We will explore the range of variables governing child production of dative sentences using a methodology parallel to Bresnan et al. (2007). First, we discuss the methodology and results of that work and develop a parallel model based on a corpus of spontaneous child speech extracted from the Child Language Data Exchange System (CHILDES, MacWhinney 2000). We then make a more direct comparison between children's production and adult's child-directed speech. Such a comparison is necessary for two reasons. First, it allows us to compare what children hear (child-directed speech) to what they produce. Given that child-directed speech is different from adult-to-adult speech on various variables (syntactic complexity (Snow 1972), prosodic features (Fernald & Mazzie 1991)), there is importance in seeing what children's actual input looks like. Second, it controls for differences in speech types between child speech and the Bresnan et al. (2007) corpus. The two models are based on fundamentally different corpora and collected in different spoken environments (e.g., telephone conversation vs. face-to-face dialogue). By comparing children's production and adult's child-directed speech we create a more similar sample where children and adults share the same conversational topics and environment.

2   Modeling the dative alternation in adult production

Bresnan et al. (2007) present a statistical model, using mixed-effects logistic regression modeling, of the adult production of dative sentences. They were the first to rigorously show the broad range of variables that independently contribute to this construction.

  Regression models permit simultaneous evaluation of all the variables in the model, assessing the strength of each factor relative to all the others. Such regression techniques have increasingly been employed to analyze and evaluate the multiple variables present in language production (Baayen 2008).

In particular, logistic regression is well-suited to the study of alternations between two choices as it is a function of a set of variables which predicts a binary outcome (see representative studies for the genitive alternation (Rosenbach 2003, Hinrichs & Szmrecsanyi 2007), the dative alternation (Bresnan et al. 2007), and the presence/absence of complementizer (Roland et al. 2006)). Further, a mixed-effects model allows generalization beyond the sample of subjects (Pinheiro & Bates 2000): the model is not restricted to the particular individuals seen in the data, but rather permits inferences concerning speakers in general.

Bresnan et al.'s study is based on spoken speech, with 2360 dative observations culled from the three million word Switchboard collection of recorded telephone conversations (Godfrey et al. 1992). Each sentence is annotated for the following variables. The theme and the recipient are annotated for "animacy", "givenness", "concreteness", "definiteness", "nominal expression type (pronoun/lexical)" and "length" (number of words). Other variables draw on properties of the verb in the dative alternation: "person", "number", "verb" and "verb semantic class". The presence or absence of a previous dative construction in the dialogue is also taken into account with "persistence", a measure of parallelism or structural repetition.[2] All the variables cited contribute significantly to explaining the variance in the data. Further, the model correctly predicts 94% of the production choices of dative sentences on unseen data, against a baseline of 79%. The baseline is obtained by always predicting the most frequent construction in the corpus.

Bresnan et al. (2007) also note that the predictive variables for the dative alternation display a clear pattern: the values "discourse given", "animate" and "definite" are all predictive of the argument occupying the first complement position in the dative construction whereas "not discourse given", "inanimate" and "indefinite" are predictive of the argument occupying the second complement position. Thus, values indicative of higher prominence align with the more prominent syntactic position, and values indicative of less prominence align with the less prominent syntactic position. This pattern corresponds to *harmonic alignment*, a phenomenon noted in the functional and typological literature whose relevance for syntax was first put forth by Aissen (1999). With the aid of the logistic regression model, this qualitative pattern is quantitatively modeled from the data.

3   Modeling the dative alternation in child production

To assess which variables are pertinent to child production, we begin with the hypothesis that the same variables pertinent to adult production play a role in child production. We then analyze the children's data with a mixed-effects logistic regression model and test whether children are indeed sensitive to the same variables as adults with respect to the dative alternation. The mixed-effects model controls for the fact that children are known to vary widely in their individual developmental trajectories (Bates et al. 1995, Clark 2003), and allows us to generalize beyond the specific children in our data. By introducing individual children as random effects in the model, the model makes an adjustment for each child representing that child's individual bias towards the prepositional dative construction.

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[2]Their data set is publicly available for download as part of the languageR package.

Age	Construction	Abe	Adam	Naomi	Nina	Sarah	Shem	Trevor	Total
2 years	NP NP	11	35	7	66	0	7	19	145
	NP PP	8	9	0	17	0	4	2	40
3 years	NP NP	20	82	6	42	8	0	11	169
	NP PP	11	19	0	21	4	4	1	60
4 years	NP NP	22	63	5	–	4	–	–	94
	NP PP	3	13	3	–	3	–	–	22
Total		75	221	21	146	19	15	33	530

Table 1: Number of Dative Utterances by Child

3.1 Data and variables

The data for the children's speech come from CHILDES, a publicly available database of children's speech produced in an ecologically natural environment. We focused on the following seven children: Abe, Adam, Naomi, Nina, Sarah, Shem, and Trevor. These children were selected based on the amount of data available for them compared to other children, in terms of both their total number of utterances and the number of utterances containing one of the variants of the dative alternation. The utterances were taken from children's production between the ages of 2 to 5 years. The data yielded a sufficient number of utterances to investigate two verbs in depth, *give* and *show*, which are the only ones considered in this study. Table 1 gives the data partition by children.

We selected only dative constructions following the "verb NP NP" (double object construction) or "verb NP PP" (prepositional dative) patterns. We did not allow *wh*-recipients, such as "Show me how to do it" or "I'll show you where" [Abe, 3;10.7], since these constructions do not alternate (cf. Pesetsky 1995).[3] We allowed constructions which lacked the preposition but where the arguments were in the NP PP order (theme, recipient), as in "I wanna show it Daddy" [Sarah, 4;5.14], "give dat Ursula" [Adam, 2;6.17]. We found 13 utterances of that type. In total, 530 dative utterances were considered for analysis.

The different variables taken into consideration when building the model for child production are essentially the same as the ones used in the adult model of Bresnan et al. (2007).

Animacy of themes and recipients Syntactic choices can be sensitive to animacy: a number of studies have found it to be an important factor in the choice of genitive constructions in English, for example, Rosenbach (2003, 2005, 2008). Animacy has also been identified as an influential factor in the dative alternation of German-speaking children (Drenhaus & Féry 2008), and also in earlier corpus studies of

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[3]We removed the data points where the theme and the recipient did not occur postverbally, i.e., in instances of topicalization, question formation or passivization. We also removed data which did not have both a theme and a recipient:

- There were 221 utterances that did not have a theme, e.g., "I give you" [Abe, 4;3.11].
- There were 150 utterances that had a theme but did not have a recipient, e.g., "You give nice lollipops" [Naomi, 2;5.8]. Only one of these had a partially-formed recipient ("I going(g) show it to my +..." [Adam, 4;2.17]), all the others we eliminated simply did not have any recipient at all.

English (e.g., Thompson 1990).

Children in the 2-5 year-old age group distinguish animate from inanimate NPs in a largely adult-like manner, both in linguistic tasks (Becker 2007) and in non-linguistic, conceptual tasks (Massey & Gelman 1988). In order to verify this, we also coded for whether a particular theme/recipient was a toy, just in case toys had any particular properties (e.g., being treated more like animates than inanimates). However toys did not differ significantly from inanimates in their effect on construction choice; therefore, the animacy variable only takes into account the opposition between true animates and inanimates in our investigations.

Length of themes and recipients   Length has long been noted as an important factor in adult speech, for example, heavy NP shift places a longer constituent at the end of the clause (Behagel 1909, Wasow 2002, Bresnan et al. 2007). We measured this factor in terms of the number of words.[4] In Bresnan et al.'s adult model, a long theme will often be placed after the recipient, leading to a NP NP construction ("Well, I guess they give the person the option for a jury"). Conversely, the NP PP construction often has a short theme ("give physicals to the rest of the family members").

Nominal expression type   The choice of a pronoun over a full NP has been known to affect the acceptability of and the preference for the different dative constructions (Green 1971, Collins 1995, Bresnan 2007, Bresnan et al. 2007, Bresnan & Nikitina forthcoming). In adult data, pronominal recipients tend to appear first, in a NP NP construction thus: "I told my husband, I've got a book in the car, give **me** the car keys, you can stay and watch this if you want to". Similarly a pronominal theme tends to come first, giving rise to a NP PP construction: "The engine messed up on me and then I gave **it** to a guy to repair". We coded for the nominal expression type of themes and recipients in the following way. Pronouns include:

  - personal pronouns (including pronouns followed by a lexical NP)
    (a) "yeah # an(d) den after our truck will [?] give **dem** back to Marianne" [Shem, 3;0.13]
    (b) "show **it** to Mike" [Abe, 2;8.6]
    (c) "she gave **them all her children** a spanking" [Naomi, 3;3.27]
  - demonstratives
    "I # I gave Bruno **that** # for that to sleep with" [Nina, 3;2.12]
  - reflexive pronouns
    "I give the bag to **myself**" [Adam, 3;7.7]

Names and indefinite pronouns (*something*, *any*, "I if if I gave you **some**, you I will gwab [:grab] it away" [Trevor, 2;8.10]) were categorized as non-pronouns.

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[4]We also considered the possibility that phonological length would be a more appropriate measure for children's speech, in part since children use fewer words in their utterances. We approximated phonological length by counting the number of syllables. However, results obtained with this measure were not significantly different from the ones obtained with a standard measure in word length. Therefore, we retained length in words as the unit of measurement.

Givenness   A number of authors have shown the importance of information structure in dative constructions: given information typically comes before new information (Collins 1995, Arnold et al. 2000, Wasow 2002, Snyder 2003, Bresnan et al. 2005). A theme that is given will therefore appear first, in a NP PP construction, whereas a recipient that is given would lead to a NP NP construction.

Following Bresnan et al. (2007), we coded givenness as a binary value, using the coding criteria from Michaelis & Hartwell (2007), in turn based on Prince (1981) and Gundel et al. (1993). We therefore coded whether a theme or a recipient had been mentioned in the previous 10 turns in the dialogue. Any referential expression, pronominal or lexical, was taken into account. Personal pronouns which refer to participants in the discourse (such as *I*, *you*) as well as demonstrative pronouns (*that*, *these*) are coded as given.

Persistence   Repetition and parallelism also play a role in how people choose a construction: speakers reuse what they have just heard or just used. Effects of syntactic persistence have been found for the dative alternation (Bock 1986, Pickering et al. 2002, Snider 2008). Syntactic priming effects have also been reported in young children (see Savage et al. 2003, Huttenlocher et al. 2004, Conwell & Demuth 2007, and references therein). Szmrecsanyi (2004, 2005) studied structural persistence from a corpus-based, variationist perspective. He found that persistence plays a significant role in linguistic choice for three different English alternations: analytic vs. synthetic comparatives, particle placement, and future marker choice. Weiner & Labov (1983) showed that persistence plays a role for passive. Interestingly, there have been no studies to date that investigate structural persistence in children using corpus data.

We encoded the persistence factor in the following way: we examined the 10 previous turns in the conversation and when a dative construction was found, we marked the choice of construction used, the speaker of that dative utterance (adult vs. child) and we counted its distance from the current dative construction by the number of clauses.

Age and MLU   We consider it likely that some of our measures (e.g., length of theme/recipient) could be confounded with developmental advances allowing for longer utterances overall. Since there is considerable variation among children, age is not a sufficient measure of developmental progress. One of the standard metrics used since Brown (1973) is the mean length of utterance (MLU), which attempts to capture the syntactic complexity of children's utterances. The CLAN program, which is linked to the CHILDES database, makes it fairly straightforward to compute the MLU for each recording session in CHILDES. We added this information to the data. However, consistent with recent research in language acquisition (Legendre 2006), none of these measures proved to be significant.

3.2 Resulting model

The final logistic regression model for the children's dative alternation is summarized in the formula in Table 2. We constructed the model in R (R: A Language and Environment for Statistical Computing) using the backward elimination method, which starts with all the variables, recursively eliminating variables one by one which do not significantly contribute to explaining the variance in the data, and stopping when the elimination of a variable would significantly reduce the model fit. Five variables turned out to

be significant ($p < .05$): length in words of the theme, length in words of the recipient, nominal expression type of theme and recipient, and structural persistence. The other variables – age, animacy and givenness – lacked predictive value and were eliminated from the final model. We tested for, but did not find, interactions between the variables. We also ensured that there was no collinearity between the variables.

As in the adult data, length was a significant predictor. A long theme will often be placed after the recipient, leading to a NP NP construction:

(a) "and she gives them **some broth without any bread**" [Naomi, 3;3.27]

(b) "why you give Diandros **all the stuff we using**?" [Adam, 4;10.23]

(c) "I gotta show Gil **some of my pictures**" [Adam, 4;2.17]

Conversely, the NP PP construction often displays a short theme:

(e) "I wanna give **that** to Poy now" [Nina, 2;9.26]

(f) "that gorilla's giving **bananas** to them" [Nina, 3;1.6]

Pronominality of theme and recipient also influences childrens choices. Pronominal recipients tend to appear first, in a NP NP construction: "dolly could go to sleep and give **him** a hug" [Nina, 2;11.06]. Likewise, a pronominal theme will come first: "give **it** to the man" [Adam, 4;0.14].

As for adults, syntactic persistence plays a role. Children tend to reuse a construction previously heard:

[Nina, 3; 1,6]

MOT: ok # let's give **him some milk**.

MOT: and what else would he like?

CHI: I gave **him some milk**.

[Nina, 2; 3, 28]

MOT: do you think the mouse will give some cheese **to Popeye**?

MOT: what is he doing?

CHI: giving cheese **to Popeye**.

Contrary to our expectations, animacy was not found to be a significant factor in the child model. However the data distribution for the two verbs under consideration, *give* and *show*, explains this fact. There is not enough variation: with both verbs, most of the recipients are animate (86.5% in the double object construction, 91.8% in the prepositional dative construction). Given the semantics of the verbs, this distribution is not surprising: one usually gives or shows something to *someone*.[5]

Givenness was also not found to be significant. Since there is potentially a confound between givenness and pronominality, we hypothesized that the effect of givenness could have been obscured by pronominality, which was highly significant. Indeed, in the data we considered, children use more pronouns as recipients and more lexical NPs as themes than adults; however, when we re-ran the model

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[5]Restricting the adult data to only two verbs does change the findings of Bresnan et al. (2007). We re-ran their model restricting the Switchboard data to the verbs "give" and "show", and found differences in the main effects. For this restricted dataset, animacy and verb type were not significant, contrary to what has been found for the whole dataset. These two variables ceased to be significant simply because there is no longer enough variation. The data distribution of the restricted dataset is similar to the distribution for the child corpus: most recipients are animate (93.2% in the double object construction, 95.1% in the prepositional dative construction).

Probability $\{\text{Response} = \text{NP PP} | X, u_i\} = \frac{1}{1+e^{-(X\beta + u_i)}}$ where:

$$
\begin{aligned}
X\beta \quad = \quad & -1.2043 \\
& -0.6199 \quad \cdot \quad \{\text{the number of words in the theme}\} & + \\
& 0.9391 \quad \cdot \quad \{\text{the number of words in the recipient}\} & + \\
& 2.7470 \quad \cdot \quad \{\text{nominal expression type of the theme = pronoun}\} & + \\
& -1.4134 \quad \cdot \quad \{\text{nominal expression type of the recipient = pronoun}\} & + \\
& -1.7065 \quad \cdot \quad \{\text{previous NP NP construction in the last ten turns = yes}\} & + \\
& 1.8621 \quad \cdot \quad \{\text{previous NP PP construction in the last ten turns = yes}\} & \\
u_i \quad \sim \quad & N(0, 0.25)
\end{aligned}
$$

Table 2: The Model Formula

on the child data excluding pronominal themes and recipients, givenness still played no role.

The model predicts the likelihood of the prepositional construction, stating the baseline value (the intercept), and quantifying the influence of each variable, viz. the coefficients (or log odds) β in the formula (see Table 2). The intercept gives the likelihood of the prepositional construction when no variables are considered. The model also accounts for variation between different speakers (random variable u_i where i is the number of speakers), assuming a normal distribution of this variance: Table 3 gives the intercept adjustments for each speaker, showing the individual bias for the dative construction. Any positive value for a coefficient in the formula increases the likelihood of the prepositional construction. Conversely, any negative value for a coefficient decreases the likelihood of the prepositional construction. Thus, the values of the coefficient of the previous NP NP construction and the length of the theme are negative as they decrease the odds of realizing a NP PP construction. The length of the recipient and the nominal expression type of the theme have positive coefficient values, as they increase the odds of the NP PP construction being used. For example, the prepositional construction is $e^{2.747} = 15.6$ times more likely when the theme is a pronoun. The relative odds of each variable can be seen in Table 4, as well as the detailed p-values and confidence intervals. This model predicts the choice of the dative construction with a high classification accuracy: 88.7%, about a 10% improvement over a baseline of 77.0% which is obtained when always predicting the most prevalent construction in the data (the NP NP construction). The C statistic provides another way of assessing the quality of the model: it is an index of concordance between the predictions of the model and the observed data. A value of 50% indicates that predictions are random, and a value above 80% indicates that the model has real predictive capacity (Baayen 2008). For our model, C is 91.3%.

3.3 Discussion

The model delivers not only information about which variables are predictive, but also the strength of their predictive power measured in terms of log odds. The model predictions are shown in Figure 1.

The bottom graph in Figure 1 shows an effect of persistence: the previous dative influences the current one. If there was a previous dative, and it was a prepositional one (PP), the current construction is more likely to be a prepositional dative. Conversely, if a double object construction was previously produced (NP), the current construction is less likely to be a prepositional dative. This is line with

9

Child	Intercept Adjustment
Abe	+ 0.056
Adam	− 0.078
Naomi	− 0.072
Nina	+ 0.216
Sarah	− 0.128
Shem	+ 0.133
Trevor	− 0.119

Table 3: Intercept Adjustments for each Child in the Mixed-effect Model

Main effects	Odds	P-Value	95% Confidence Interval
theme type=pronoun	15.60	0.0000	7.83–31.08
recipient type=pronoun	0.24	0.0000	0.12–0.49
theme length	0.54	0.0175	0.33–0.90
recipient length	2.55	0.0211	1.15–5.68
previous dative=NP	0.18	0.0000	0.08–0.40
previous dative=PP	6.44	0.0000	2.70–15.34

Table 4: Odds, P-Values and Confidence Intervals of the Significant Main Effects

previous reports of priming in child production that were obtained using experimental methods (Branigan et al. 1995, Savage et al. 2003, Huttenlocher et al. 2004). It is of interest that there was no interaction with age: children were more likely to produce a prepositional dative following a similar dative regardless of age. That is, they showed sensitivity to construction type early on.

The probability of occurrence of the prepositional dative decreases when the length of the theme increases, as the linear relationship shows in the upper right corner of Figure 1. The upper left corner shows that the inverse occurs for the length of the recipient: the probability of occurrence of the prepositional dative increases as the length increases.

If the theme is realized as a pronoun, the probability of the prepositional dative is greater than if the theme is realized as a lexical NP (center right in Figure 1). The center left shows the inverse: if the recipient is realized as a pronoun, the probability of the prepositional dative is less than if the recipient is realized as a lexical NP.

Thus far, we have discussed the variables in terms of predicting the likelihood of the prepositional dative construction, but these results can also be viewed from the perspective of predicting which syntactic position the argument will fill. For instance, referring to the center left of Figure 1, if the recipient is pronominal, it favors the double object construction (i.e., it disfavors the prepositional dative construction), in which the recipient appears in first position. Similarly, if the theme is pronominal (center right of Figure 1), it favors the prepositional dative construction, whereby the theme will appear in first position. The upper left corner and upper right corner of Figure 1 are in a mirror relation to one another, as it is the case for the center left and center right graphs. Clearly then, there is a correspondence between the val-
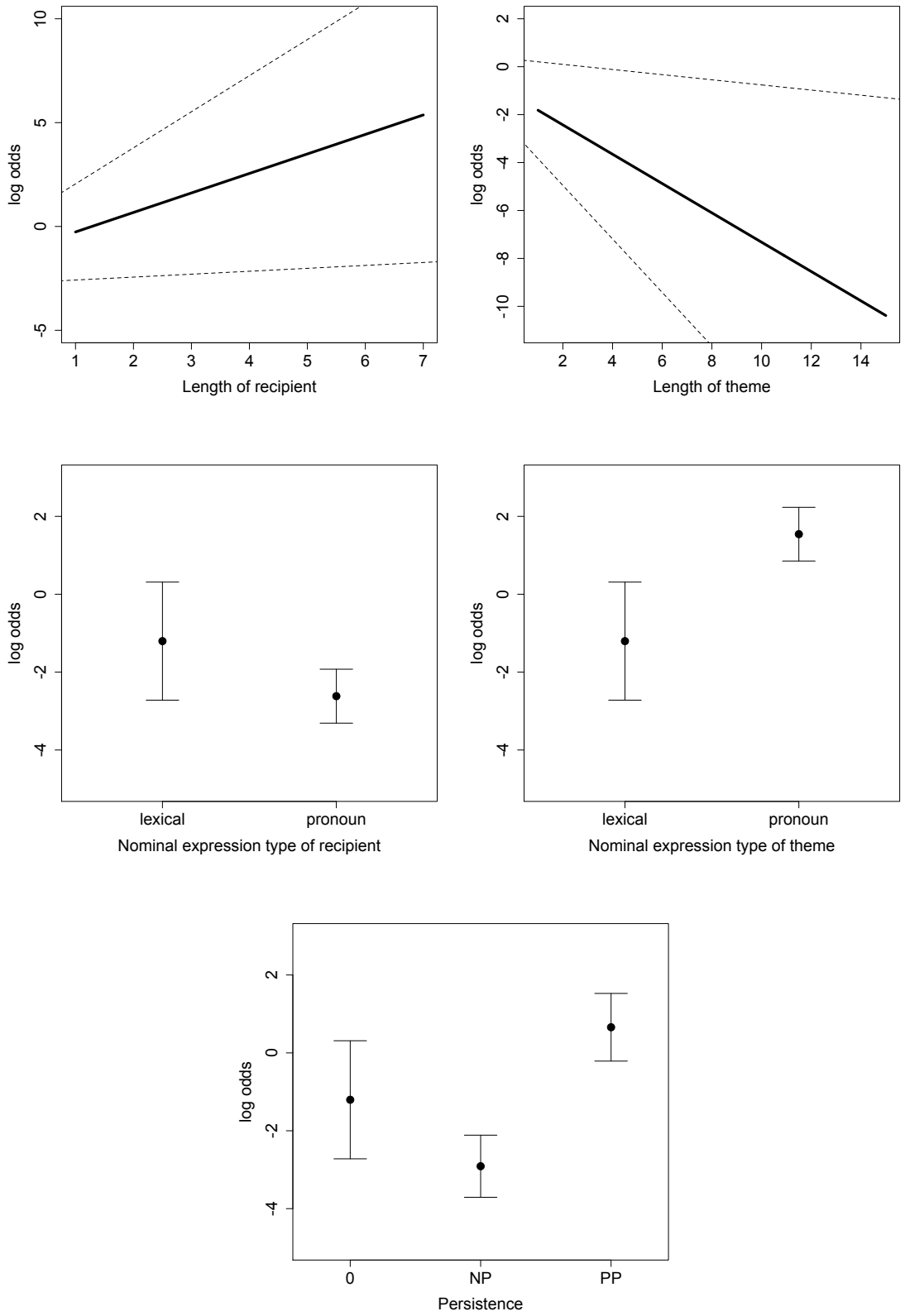
Figure 1: Log odds of Prepositional Dative Given the Main Effects

ues of the variables and syntactic position: shorter and pronominal NPs (more prominent) align with the first syntactic position of the dative construction, while longer and non-pronominal NPs align with the second position, as schematically represented in Figure 2. This model then shows harmonic alignment effects in children's production data, parallel to the findings in Bresnan et al. (2007) for adults.

shorter	>	**longer**
pronoun	>	**non-pronoun**
V NP **NP**		V recipient **theme**
V NP **PP**		V theme **recipient**

Figure 2: Harmonic Alignment Effects Observed in Child Dative Constructions

3.4 Individual bias

The global trends reported above hold locally for each child, both in terms of direction and magnitude of response. As can be seen in Figures 3 through 7, the magnitude of the responses varies by child, but the model informs us that this variation is not significant: there is little variation in the intercept adjustments by child (Table 3). Moreover, as the graphs show (Figures 3 through 7), the direction of the response is constant by child: the trends in the effects are similar for each child. Figures 3 and 4 respectively show the effects of the theme and recipient length for each child, and the lines are nonparametric smoothers showing the trends in the data. Figures 5 and 6 give the nominal expression type effects of the theme and the recipient for each child. Finally, Figure 7 draws the effects of persistence for each child. The graphs also show that all the children in our sample use both variants of the construction.

3.5 Interim conclusion

The statistical models and the data they were run on provide additional, naturalistic evidence for the importance of specific factors while controlling for others. Researchers have previously found effects of syntactic persistence on children in experimental settings (i.a., Savage et al. 2003)but have not looked for similar effects in spontaneous speech. The current findings offer further support for these effects on children of a very young age and in naturalistic settings. Crucially, the use of statistical models controls for different factors that present difficulties in experimental settings, such as information structure and communicative role (e.g., the speaker of the last similar construction).

The findings show that the overall picture of child production of dative sentences is much the same as what Bresnan et al. (2007) found for adults. First, the results show that children produce alternating forms early on and that construction choice in child production is governed by multiple variables. Moreover, variables that explain well the adult production also explain the child production. Second, the significant variables in the child model align harmonically. Finally, these findings are robust and found across the entire sample from CHILDES.
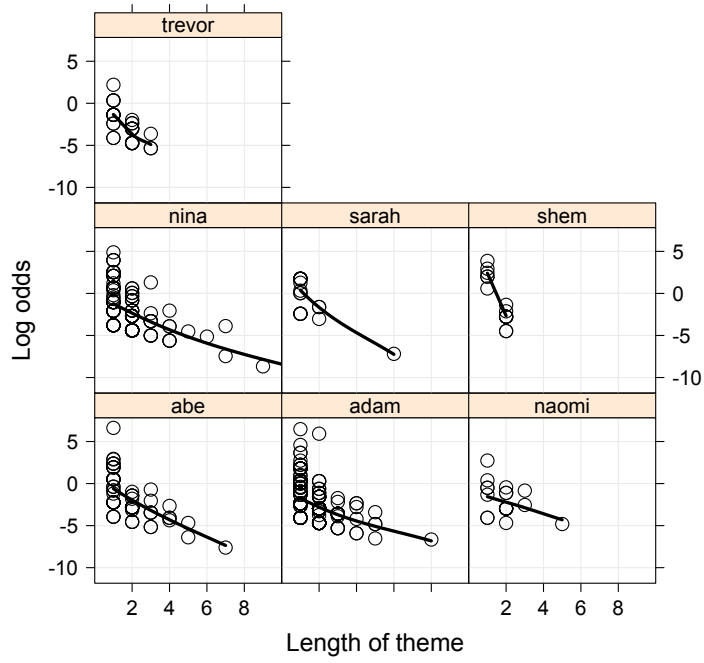
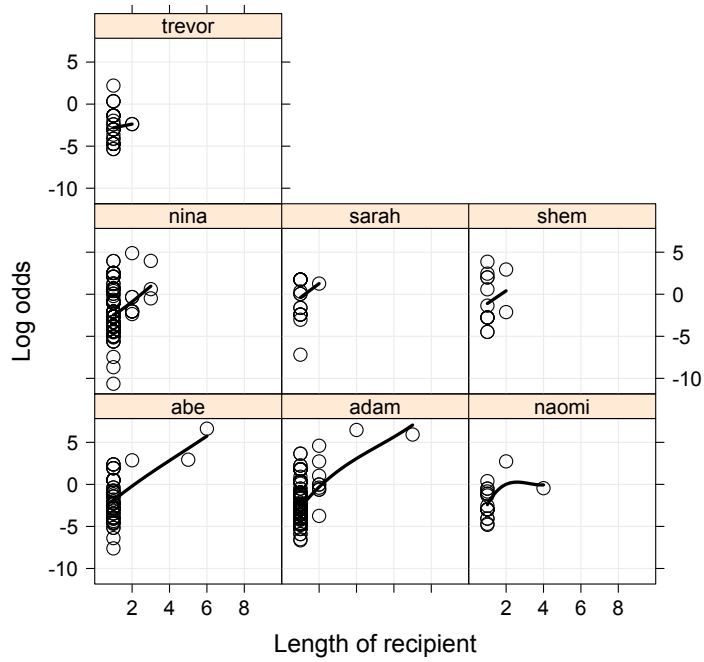Figure 3: Effects of the Length of the Theme by Child

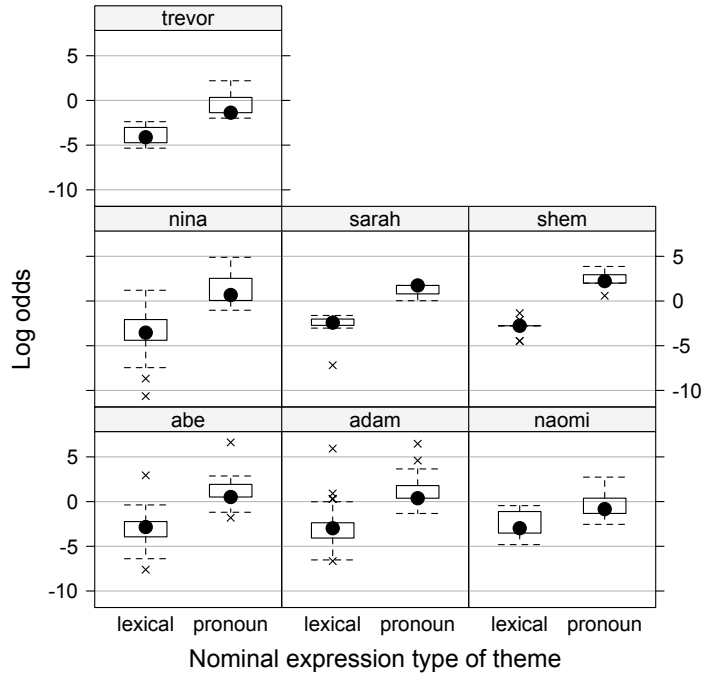Figure 4: Effects of the Length of the Recipient by Child

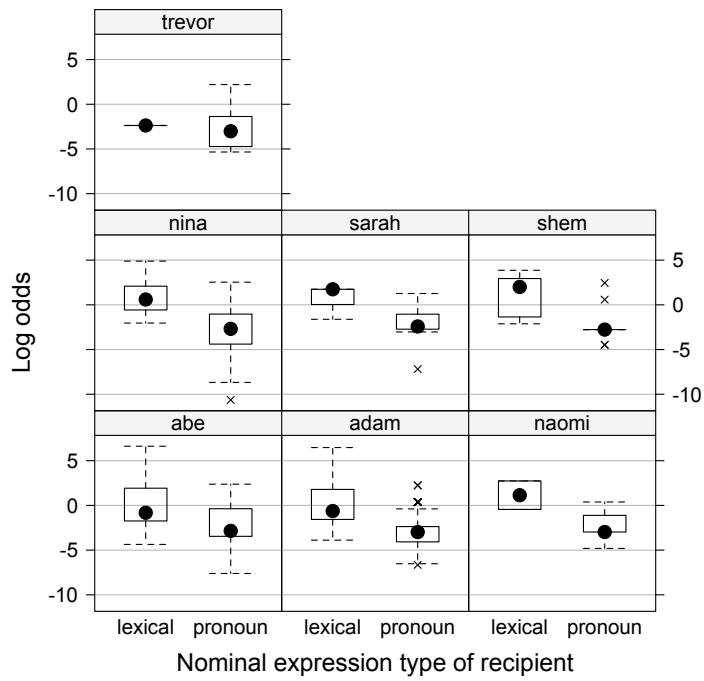Figure 5: Effects of the Theme Nominal Expression by Child

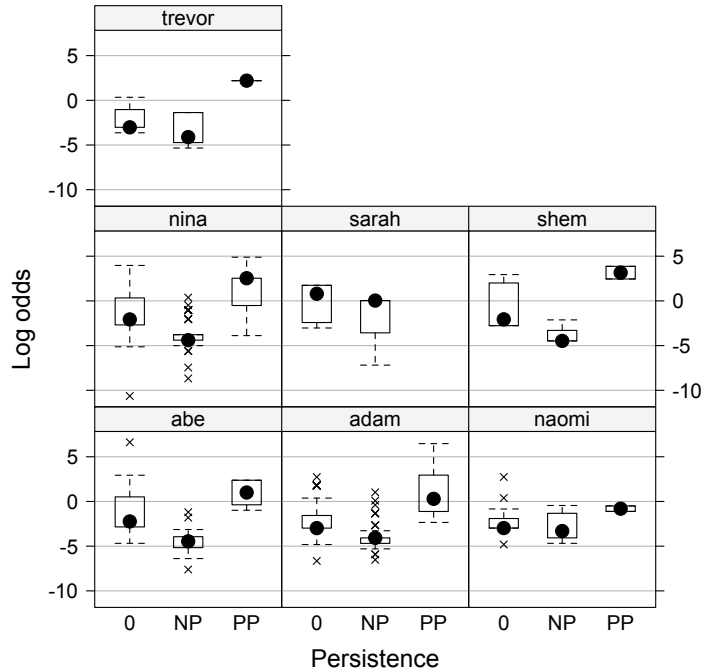Figure 6: Effects of the Recipient Nominal Expression by Child

Figure 7: Effects of Persistence by Child

4 Comparison with child-directed speech

While the model of child production of the previous section follows the trend expected from Bresnan et al. (2007), given that the two models are based on different corpora and conversation settings, any comparison can be no more than impressionistic. If we compare children's production with the production of their caretakers, we directly compare what children produce with the input they receive, enabling us to see if children are sensitive to the same variables influencing adult production in the same context. It is also possible that the adult-to-adult production examined in Bresnan et al. differs qualitatively from adult production towards children—adults speaking to children may not expose them to all the full range of variables used in adult-to-adult conversations. By examining adult child-directed speech, a comparison between child production and relevant adult production becomes possible. It allows us to address the important question of the influence of the input children receive.

4.1 Modeling the dative alternation in child-directed speech

To investigate the dative alternation in child-directed speech, we used the same resource as for the initial child data, the CHILDES database, and focused on the adult utterances occurring in the exchanges with three of the children studied in the previous section: Adam, Nina and Shem. The caretakers of these three children provided us with a number of datives comparable to the data we had for the child model. As in the case of the children's data, we only took dative constructions with the verbs *give* and *show*, yielding 788 data points, and coded the variables following the procedure previously outlined.

15

Child	Caretaker	Number of adult dative utterances		Total
		NP NP	NP PP	
Adam	caretaker 1	116	56	172
	caretaker 2	24	11	35
Nina	caretaker 1	337	106	443
Shem	caretaker 1	95	29	124
	caretaker 2	12	2	14
		584	204	788

Table 5: Number of Dative Constructions Uttered by the Children's Caretakers

Main Effects	Odds	P-Value	95% Confidence Interval
intercept	2.07	0.3547	0.44–9.62
theme type=pronoun	94.09	0.0000	32.11–275.69
recipient type=pronoun	0.07	0.0000	0.03–0.15
theme length	0.27	0.0000	0.15–0.48
recipient length	2.66	0.0019	1.43–4.95
previous dative=NP	0.32	0.0109	0.14–0.77
previous dative=PP	11.87	0.0003	3.04–46.28
theme givenness=new	0.41	0.0201	0.19–0.87

Table 6: Odds, P-Values and Confidence Intervals of the Significant Main Effects in the Child-Directed Speech Model

The dialogues typically had one primary adult interlocutor, but there were occasionally other adult speakers interacting with the child. Adult speakers who had less than 10 utterances were removed, yielding 5 different speakers for the three children. Table 5 shows the number of speaker utterances according to the child participating in the dialogues.

We applied the same modeling technique and variable selection that was used for the child data: a mixed-effects logistic regression model predicting the choice of dative construction. All the variables that were significant for the child data were also significant in the child-directed model: pronominality of the theme and the recipient, length of the theme and the recipient, and persistence. As in the case of the children, animacy was not significant in the child-directed model—this is probably due to the semantics of the verbs: most recipients in both constructions are animate (92.9% in the double object construction, 93.6% in the prepositional construction). Unlike for children, givenness was a significant factor for adults.

The estimates of the variables, as well as the model intercept, are given in terms of odds in Table 6. The classification accuracy of the model is very high: 94.4% (against a baseline of 74.1% when always predicting the NP NP construction). The C statistic is also high: 97.5%. The intercept adjustments for each adult speaker are given in Table 7.

Child interlocutor	Adult speaker	Intercept Adjustment
Adam	caretaker 1	− 0.199
	caretaker 2	+ 0.066
Nina	caretaker 1	+ 0.450
Shem	caretaker 1	− 0.317
	caretaker 2	+ 0.010

Table 7: Intercept Adjustments for Each Adult in the Mixed-effect Model for Child-Directed Speech

Main Effects	Odds	P-Value	95% Confidence Interval
intercept	1.08	0.8923	0.35–3.39
group=child	0.67	0.3894	0.27–1.67
theme type=pronoun	129.43	0.0000	47.72–351.03
recipient type=pronoun	0.075	0.0000	0.03–0.17
theme length	0.38	0.0000	0.26–0.55
recipient length	2.48	0.0000	1.55–3.94
previous dative=NP	0.23	0.0000	0.13–0.41
previous dative=PP	7.41	0.0000	3.55–15.43
theme givenness	0.50	0.0071	0.30–0.83
group=child ∗ recipient type=pronoun	3.02	0.0329	1.10–8.32
group=child ∗ theme type=pronoun	0.08	0.0000	0.03–0.25

Table 8: Odds and P-Values of Main Effects in the Conjoined Model

4.2 Conjoined model

We cannot draw conclusions about the similarities and differences among different populations from isolated models of different datasets, since there is no way to determine whether the model differences are significant. To properly compare child and child-directed speech production of dative sentences, we constructed a conjoined model pooling the data together from both studies, and examined how the group variable (children vs. adults) interacted with the other predictors. This will show us whether the different variables work in different ways in the two populations.

The conjoined mixed-effects regression model obtained a high classification accuracy (92.1% against a baseline of 75.3%). A C statistic of 95.4% reinforces the quality of the model. Table 8 shows the conjoined model, in terms of odds, as well as listing the p-values and confidence intervals.

We used speaker as a random effect to take into account speaker variation. The intercept adjustments for each speaker are given in Table 9. All the variables that were significant in either model separately were also significant in the conjoined model. We found two interactions: nominal expression type of the theme and the recipient (pronoun vs. lexical NP) interacted with group (children vs. adults).

Speaker	Intercept Adjustment
Abe	+ 0.114
Adam	− 0.123
Naomi	− 0.134
Nina	+ 0.294
Sarah	− 0.194
Shem	+ 0.257
Trevor	− 0.199
Adam caretaker 1	− 0.166
Adam caretaker 2	+ 0.049
Nina caretaker 1	+ 0.402
Shem caretaker 1	− 0.272
Shem caretaker 2	+ 0.257

Table 9: Intercept Adjustments for Each Speaker in the Mixed-effect Model for Both Adult and Child Data

4.3 Discussion

The overall patterns of the separate models are echoed in the conjoined model: all the variables influence alternation choice in the same way for children and adults. Both show structural persistence: they produce more prepositional datives following a prepositional prime. Both show length effects with longer recipients favoring the prepositional dative, and for both a lexical recipient favors the prepositional dative construction as does a pronominal theme.

The difference between child and adult populations is in the sensitivity to the shared variables. The interaction effects for the nominal expression type of the theme and the recipient in predicting the NP PP construction (Figure 8) show that the directions of the effects are the same, but that children and adults differ in the degree to which the factor influences their choice. In particular, the nominal expression type of the recipient and theme has a greater influence on the adults' production choice, as indicated by the steeper slope of the lines representing the effect of pronominality for adults (solid lines). Judgments from the literature have shown that there is a strong dispreference against *V NP Pronoun* structures when the NP is lexical ("give the boy it") or even when the NP is pronominal ("gave her it"); however, this dispreference is not absolute, as discussed in Bresnan & Nikitina (forthcoming). Children do not manifest this dispreference to the same degree ("give me it Mommy" [Nina 3;2.4], "this is the last time I'm gon (t)a give you it" [Abe 3;6.19], "Daddy # can you take that out and show me it ?" [Abe 3;8.17]). Children may use stressed pronouns more, which would make a pronoun more acceptable in final position. Further prosodic or deictic differences in child speech could underlie the difference in placement of pronominal themes. Further data from audio sources could provide insight into such differences.

Another apparent distinction between child and adult production lies in the way pronominality and givenness affect syntactic choice. Givenness of theme was significant in the adult model but not in the child model. The conjoined model showed that pronominality had more of an effect on the syntactic
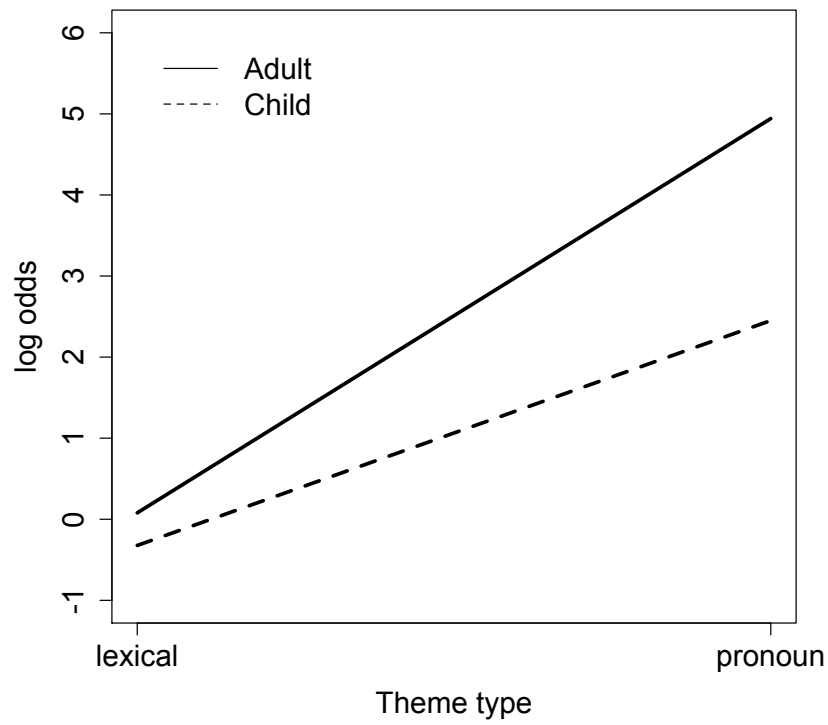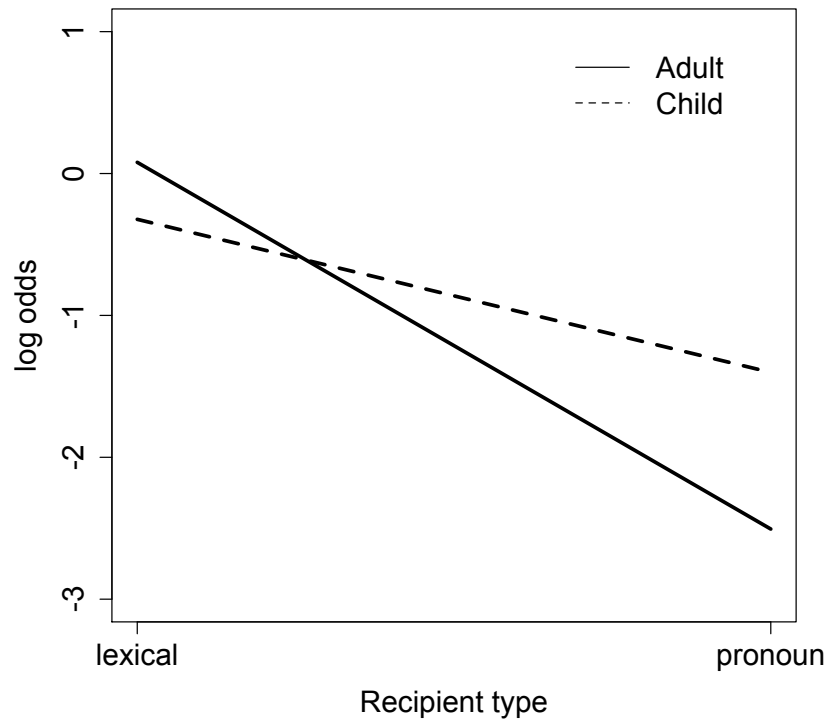
Figure 8: Interaction Effects for Nominal Expression Type of Theme and Recipient

choices of adults compared to children. These patterns could reflect differences in how givenness and pronominality affect syntactic choices. But they might also reflect differences in how children and adults use referring expressions, specifically in relation with givenness, as might be expected given the literature on the development of referential production patterns (e.g., Hickmann & Hendricks 1999, Song & Fisher 2007). To better understand this result, we looked at the relation between givenness and pronominality in child and adult productions. Figure 9 shows the proportion of pronominal forms children and adults use for new and given themes. The main difference lies in the use of pronouns for new entities. Children and adults used a similar proportion of pronouns for given entities (34.7% vs. 38.7%, $\chi^2 = 1.32$ ($N = 763$), p $= .14$) but children were more likely to refer to a new entity with a pronominal form (9.5% vs. 1.8%, $\chi^2 = 18.43$ ($N = 590$), p $< .001$). The results show that children are sensitive to givenness as seen by the higher proportion of pronouns for given entities compared to new ones, but they use more pronouns for new entities than adults. This is in line with previous findings showing that children are sensitive to given/new distinctions early on (Allen 2000, MacWhinney & Bates 1978) but still tend to use pronouns more than adults (Clancy 1992).

In sum, there are more cases in children's production than adults where the theme is both new and pronominal. In considering how these characteristics of children's use of themes interact with dative construction choice, we can hypothesize that children are faced with a "cue clash": the pronominality of the theme pushes children towards a NP PP realization while its new discourse status pushes them towards a NP NP realization. The effect of givenness on children's dative choices may be masked by the larger proportion of cases where the influence of givenness and pronominality lead towards different constructions. Similarly, children's syntactic choices may be less sensitive to pronominality (see Figure 8) because in more cases, there is a clash between pronominality and other cues. Under this interpretation, children and adults do not differ in the way givenness influences dative choice but in the way referential form and discourse status interact.

5   Conclusion

This paper has developed multi-variable models of child and adult production of the dative construction. The model we establish to compare children and adult productions from the same corpus demonstrates a strong similarity in the variables at play for both populations. Children mirror the adult production patterns in their input, showing sensitivity to production probabilities found in adult production. Our results suggest that, for the dative construction, child speech only differs from the speech of their adult interlocutors in degree, not in kind.

These findings lend support to much current work in language acquisition which contends that there is a continuity between the grammars, and the parsing mechanisms, that young children and adults use (Arnon (in press), Goodluck 2007, Trueswell et al. 1999). Children's syntactic choices, like those of adults, were shown to be influenced by multiple factors from early on. These results enhance a view of language learning in which attainment of adult-like competence is assisted by the sensitivity and attention to complex distributional patterns. Further, the models shown here demonstrate that child production patterns echo the probabilities of adult production patterns, which is unexpected if children are assumed to go through a period in which they maximalize to only one of the alternation's variants. Some studies
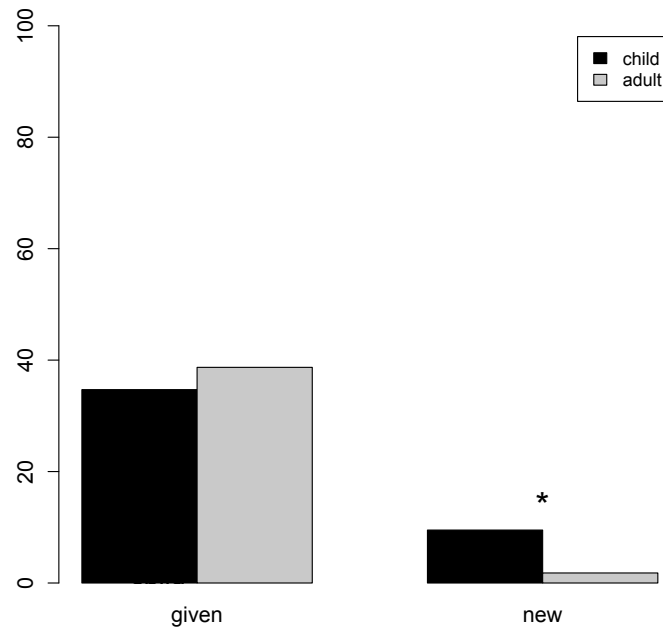
Figure 9: Proportions of Pronominal Forms in New and Given Themes for Children and Adults.

have shown evidence that children fare worse on probability matching tasks than adults (Hudsom Kam & Newport 2005; see discussion in Ramscar & Gitcho 2007); however, the naturally-occurring data considered here manifests an apparent sensitivity on the part of the children to production probabilities: they replicate subtle patterns found in their input. This study suggests that the learning process takes place incrementally: children are able to pick up on some of the cues available in their input, but will need to gradually refine these cue weights to get to adult-like production where, for instance, pronominality matters more. The results also demonstrate the dynamic nature of language learning (Smith & Thelen 1993): changes happening in one area (e.g., reduction of pronominal reference for new entities) will influence patterns in another area (the effect of givenness on dative choice).

This study has also shown that statistical modeling techniques can yield insight into the variables at play in children's speech production, as well as into the way they compare to the ones used by adults. It is a fruitful technique to investigate patterns of use within an age group, across age groups, and between different populations (for example adults and children). These techniques can be extended to examine the different ways adults talk to children vs. other adults. Further research may shed light upon why the differences between these patterns of production were observed, for instance by exploring interactions with processing capacities, such as resource limitations. Given the size of the corpus, our results are promising rather than definitive, yet already indicate that new evidence can be brought to bear on the acquisition of alternations using quantitative modeling methods.

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