Modeling the Dative Alternation in English Early Child Language

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1 Introduction

How do preferences for syntactic orderings develop in child speech, and what affects children's syntactic choices? Prior research, while fruitful, faces several limitations. First, the number of utterances included for analysis is relatively small (De Marneffe et al., 2012; Goldberg and Suttle, 2010; Yang and Montrul, 2017; Liu et al., 2023). Second, previous research has mostly attended to only a narrow age span. Lastly, regarding constituent ordering in particular, existing studies fall short in terms of the linguistic factors examined (De Marneffe et al., 2012; Liu et al., 2023).

This study investigates syntactic ordering preferences in child and parent speech in English, using the dative alternation as the test case. An English dative construction can be realized as either a double object or a prepositional object structure. In the double object structure (e.g., (1a)), the head verb (*give*) takes a direct object (*the book*) and an indirect object (*me*). The semantic role for the direct object is *theme*, and that for the indirect object can be either *recipient* as in (1a), or *beneficiary* as in (2a). In the prepositional object structure (e.g., (1b)), the head verb has the same direct object, the semantic role of which is still theme, yet the recipient (or the beneficiary in (2b)), *me*, is realized as the prepositional object of the head verb.

(1) a. **give** [$_{NP}$ me] [$_{NP}$ the book]
b. **give** [$_{NP}$ the book] [$_{PP}$ to me]

(2) a. **bake** [$_{NP}$ me] [$_{NP}$ the cake]
b. **bake** [$_{NP}$ the cake] [$_{PP}$ for me]

With the English dative alternation, we ask: (1) what are the developmental trajectories of the double object and the prepositional object structure? (2) at what developmental stage do preferences for one alternative emerge? (3) how does children's production of the dative alternation compare to parent production along their developmental trajectory? (4) what linguistic factors affect children's production of the dative alternation?

To address these questions, we need English production data from children and parents spanning large age ranges, as well as annotations for different linguistic constraints. The latter, in particular, is likely to blame for the limitations in prior literature. Here, we address all these limitations with a data-driven approach. Leveraging naturalistic child-parent interactions and computational techniques, we present the largest-to-date dataset of the dative construction containing 36,509 utterances (*child*: 8,053; *parent*: 28,456). With this dataset, we applied growth curve modeling (Section 3) followed by logistic regression analysis (Section 4).

2 Dative dataset construction

We extracted all child and parent utterances from the English sections of CHILDES (MacWhinney, 2000) and searched for verb phrases (VPs) in which the head verb belongs to either the dative or the benefactive class (Levin, 1993), and occurs in either a double object (V-NP-NP) or a prepositional object structure (V-NP-PP). This yielded an initial data set of 43,156 utterances that potentially contain dative structures. Candidate dative structures had to satisfy two criteria: (1) the verb has a direct object as the theme and either an indirect object or a prepositional object as the recipient or beneficiary; (2) the verb expresses some action of (metaphorical) transfer from the subject/agent of the sentence to the recipient/beneficiary. Two annotators with Linguistics training cross-annotated 1,000 utterances with a percent agreement score of 95.20%. Overall, we manually annotated a set of 10,709 utterances from the initial data set (hereafter referred to as the *gold-standard*). Of these utterances, 8,718 were considered as having a dative construction (with an annotation label of *yes*), while the remaining were not (with an annotation

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Age bin (months)	Speaker	N of V-NP-NP	N of V-NP-NP	Proportion of V-NP-NP	Proportion of V-NP-NP
12-18	Child	2	0	100	0
	Parent	1,384	731	65.44	34.56
18-24	Child	109	28	79.56	20.44
	Parent	2,115	1,033	67.19	32.81
24-30	Child	647	319	66.98	33.02
	Parent	5,617	2,239	71.05	28.50
30-36	Child	1,088	716	60.31	39.69
	Parent	4,688	1,761	72,69	27.31
36-42	Child	881	450	66.19	33.81
	Parent	2,518	994	71.70	28.30
42-48	Child	613	185	76.82	23.18
	Parent	1,076	327	76.69	23.31
48-54	Child	470	140	77.05	22.95
	Parent	895	291	75.46	24.52
54-60	Child	1,217	356	77.37	22.63
	Parent	1,253	400	75.80	24.20
60-66	Child	156	51	75.36	24.64
	Parent	195	66	74.71	25.29
66-72	Child	110	24	82.09	17.91
	Parent	200	103	66.01	33.99
> 72	Child	350	141	71.28	28.72
	Parent	380	190	66.67	33.33

Table 1: Relative production frequency and proportion of the double object structure (V-NP-NP) and the prepositional object structure (V-NP-PP) in child and parent production given each 6-month age bin of the children.

label of *no*). We randomly split the gold-standard set into training and test sets at a 4:1 ratio, three times. For each random split, we built a BERT-base (Devlin et al., 2019) neural binary classifier (dative or not); the final classification performance was measured as model prediction accuracy averaged across the three test sets, yielding an average accuracy of 94.36%, indicating that our approach is effective. With that in mind, we used the same binary classifier architecture and trained it on all utterances from the gold-standard set. We then applied the trained classifier to the remaining cases in the initial dataset.

Label	**Accuracy**
yes	98.43%
no	84.05%

Table 2: Classification accuracy for each label for the gold-standard dative utterances.

Role	**Structure**	N
Child	double object	5,643
	prepositional object	2,410
Parent	double object	20,321
	prespositional object	8,135

Table 3: Descriptive statistics for the dative constructions in English child and parent production.

One thing to note here is that when comparing the prediction results for the gold-standard set given different annotation labels (Table 2), the classifier seems to do very well in terms of identifying utterances that do contain the dative construction, but its performance fall short when it comes to correctly determining an utterance as not having a dative structure. Therefore, after obtaining automatic annotations for the remaining utterances from the initial dataset, we manually inspected all cases that were predicted as *no* by the classifier, and identified additional cases that should have been considered as including a dative structure. Descriptive statistics for the final dative dataset in our analysis, which is restricted to utterances produced by children who are at least 12-months-old and their parents, is presented in Table 3.

3 Growth curve modeling

We used children's age as index of their developmental stage, and divided our final dataset into 6-month age bins (Liu and Jasbi, 2021; Yurovsky et al., 2016).[1] We calculated the respective production frequency and proportion of the direct and prepositional object structures in child and parent production across different age bins. As illustrated in Table 1, based on our dataset at least, children start to produce the double object structure between 12 to 18 months ($N = 2$; *give me some* and *give me those*); their production of the prepositional object structure emerges between 18-24 months,

[1]We experimented with 3-month age bins as well; there was no qualitative difference in the results; therefore we continued with analysis based on the 6-month age bins.

where both *to*-datives and *for*-datives are attested. In both child and parent speech, the production frequency for the double object structure is proportionally higher than that of the prepositional object structure along children's developmental trajectory. The proportion of the double object structure in children's production of the double object structure starts higher (79.86%; N of double object datives: 111) than that in parent production (66.48%; N of double object datives: 3,499) during the age range of 12 to 24 months, then gradually drops below parents' production level from 24 to 42 months; after that, the proportion of the double object structure in child speech is consistently higher than what is observed in parent production.

In order to further probe the overall developmental trajectory of the dative alternation in child production, we used logistic growth curve analysis (Kemper et al., 1995). To perform this analysis, we adopted the measure of "cumulative (moving) ratio" from time series analysis (Wei, 2006). The cumulative ratio $R_{s,t}$ for an alternative s at an age bin t, is the sum of the number of that alternative from the first age bin to age bin t, divided by the sum of all utterances (not just the dative alternation) produced between the first age bin and age bin t.

$$R_{s,t} = \frac{\sum_{i=1}^{t} n_{s,i}}{\sum_{i=1}^{t} n_i} \quad (1)$$

We applied the Gompertz curve (Gompertz, 1825) to model the cumulative ratio $R_{s,t}$ at each *monthly* age bin of the children. This model makes several basic assumptions. First, there is an overall maximum production ratio a (upper asymptote) of a certain syntactic structure in child speech, and a lowest production ratio l; here we assume that children start with not producing this structure at all, thereby setting l with a value of 0. Second, the upper asymptote is not constant throughout children's developmental trajectory, in the sense that children begin with a production ratio of zero to eventually reaching the maximum production level. Third, the growth from no production of the structure to the upper asymptote level is not linear (an assumption that can actually be addressed based on observations from Table 1); children's production ratio rapidly increases at first until it reaches time interval i (time interval referring to children's age in this case), the growth then gradually slows down until the production ratio is at the upper threshold and stays relatively stable afterwards. The growth rate b of the curve represents the rate of growth across all time intervals; a larger value for b corresponds to quicker growth towards the upper asymptote. The rapid growth period and the slowdown period, as separated by the inflection point i, do not need to be symmetrical. Based on these assumptions, the Gompertz curve model thereby consists of four parameters: the upper asymptote a, the lower production ratio l, the inflection point i (e is Euler's number), and the growth rate b:

$$R_{s,t} = l + a \times e^{-e^{(-b \times (t-i))}} \quad (2)$$

We fit the growth curve models using the statistical package $brms$ (Bürkner, 2017) from R version 4.1.1 (R Core Team 2018) to the double object and the prepositional object structures in child production, respectively. Since we do not have enough data for each individual child, our models did not include the children of the utterances as random effects. We adopted uniform priors with reasonable bounds for the three parameters of the growth curve models other than the lowest production ratio l (which we set to be 0). In particular, we set the bounds for the prior of the inflection point to be between 12 to 72 months, with the logic that children's development of the dative alternation will mostly happen during this age period. Each model ran four chains; each chain had 4,000 iterations, with 2,000 discarded as warm-up. The 95% credible interval (CI) for each parameter was derived from their respective posterior distribution.

$$a \sim Uniform(0, 10)$$
$$b \sim Uniform(0, 3)$$
$$i \sim Uniform(12, 72)$$

Figure 1 illustrates the predicted growth curves for the two syntactic alternatives. Again, it appears that the production of the double object structure starts slightly earlier than that of the prepositional object structure, confirming our observations in Table 1. In comparison, the production level of the double object structure continues to be higher along children's developmental trajectory, along with an upper asymptote level (β=3.30, 95% CI = (3.27, 3.32)) higher than that for the prepositional object structure (β=1.38, 95% CI = (1.37, 1.38)). The inflection point for the double object structure is also estimated to be significantly later (β=31.42, 95% CI = (31.04, 31.78) vs. β=29.64, 95% CI = (29.36, 29.91)), meaning that children reach maximum growth for this structure at a later stage; this is further reflected by the growth rate, which is

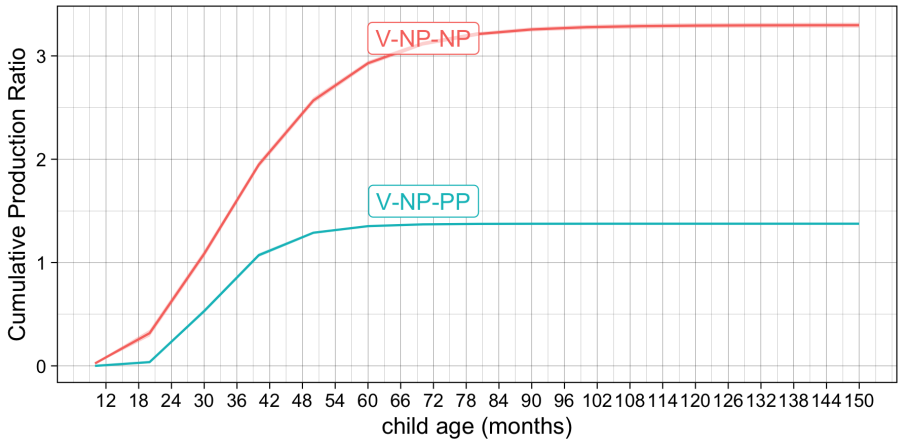

Figure 1: Predicted Gompertz growth curves for the dative alternation. The x-axis is age in months, and the y-axis represents cumulative production ratio per thousand utterances.

smaller for the double object structure (β=0.07, 95% CI = (0.07, 0.08); for the prepositional object structure: β=0.13, 95% CI = (0.13, 0.14)), indicating that children take a longer time in general to reach maximum production level for this structure.

4 Logistic regression analysis

Factors of interest For each dative structure, we annotated the semantic class of the head verb (Bresnan et al., 2007). For both the theme and the recipient/beneficiary, we annotated: (1) length; (2) givenness (whether the theme or the recipient/beneficiary has occurred in the previous 10 utterances); (3) nominal type (lexical, personal pronoun, reflexive, demonstrative); (4) animacy; (5) toyhood (whether the nominal is a toy for the child). The annotations for the aforementioned six factors were performed similarly to our semi-automatic identifications of the dative construction. In addition, we automatically derived children's age, utterance length, syntactic persistence (whether there is another dative structure prior to the current one), and exact repetition (whether the current dative instance is an exact repetition of the prior dative structure).

Regression analysis To probe the effects of the factors, we applied logistic regression predicting the prepositional object structure; the models were fit to child and parent production data combined using the $lme4$ package (Bates et al., 2015) from R version 4.1.1 (R Core Team 2018). The verb lemma of each utterance was not eventually included as a random effect given that the variance induced by individual verb lemmas was small; 68 of the 131 unique verb lemmas were each associated with fewer than 10 utterances. For similar reasons, the speaker of each utterance was excluded from the model. The final model was determined via stepwise forward regression. We found significant effects for the length and nominal type for both the theme and the recipient/beneficiary, as well as structural persistence. In terms of structural persistence, it appears that when there is another V-NP-PP structure mentioned in prior context (the previous 10 utterances), the more likely the current dative structure is realized as the prepositional object structure (β=0.98, $p < 0.001$); on the other hand, we see the opposite pattern when the prior dative instance is a double object structure (β=-1.01, $p < 0.001$), meaning that a V-NP-NP structure in previous context is less likely to lead to a prepositional object structure in the later production. These observations hold when we controlled for exact repetition, indicating that overall there is a pronounced role for structural persistence in the production of the dative alternation, similar to what has been attested for second language learners (Gries, 2019). Two points are worth noting here. First, there did not seem to be any significant interaction between the speaker role (child or parent) with any other factors of interest, suggesting that these factors affect children's and parents' ordering preferences in comparable ways. Second, the model did not end up including interaction effects between age and other factors, indicating that the roles of the investigated factors are effective in child production at an early age, and persist as children continue their language development.

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