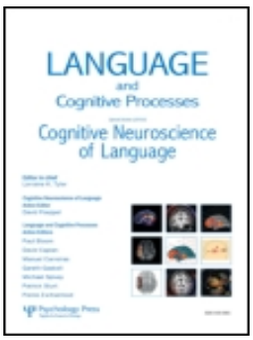

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A statistical model of the grammatical choices in child production of dative sentences

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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 analyse child and child-directed datives extracted from the Child Language Data Exchange System corpus. Such models allow us to investigate the collective and independent effects of multiple factors simultaneously. The results show that

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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 that there is a usage-based continuity between child and adult grammars. Furthermore, they highlight the utility of analysing children's speech from a multi-variable perspective, and portray a learner who is sensitive to the multiple cues present in her input.

Keywords: Language acquisition; Language production; Dative alternation; Multi-variable models.

In producing language, we are constantly making choices. We choose between the different lexical items and syntactic realisations that could be used to convey our message. We decide which perspective we will take in describing an event, and how much we want to sound like the people we are talking with. All these choices (phonological, lexical, syntactic) show pervasive effects of linguistic probabilities: adult speakers are more likely to produce linguistic elements that are more probable, where probability is driven by a host of context-dependent (e.g., accessibility of a certain label within a referential pact), and context-independent (e.g., word frequency) factors (Brennan & Clark, 1996; Jaeger, 2010; Jurafsky, Bell, Fosler-Lussier, Girand, & Raymond, 1998).

By investigating what drives speakers' choices we learn about the linguistic units they attend to and the information they rely on in producing speech. For example, while speaking, adults continually synchronise their articulatory effort to the probabilities of features of the current linguistic context, so that redundant, more predictable information is compressed in pronunciation (Aylett & Turk, 2004; Bell et al., 2003; Bell, Brenier, Gregroy, Girand, & Jurafsky, 2009; Gregory, Raymond, Bell, Fosler-Lussier, & Jurafsky, 1999; Jurafsky et al., 1998; Pluymaekers, Ernestus, & Baayen, 2005). This effect appears even with the higher-level probabilities of alternative syntactic structures: pronunciation is reduced in more probable syntactic realisations (Gahl & Garnsey, 2004; Tily et al., 2009). How likely a specific realisation is depends on multiple semantic and pragmatic factors. For instance, which variant of the dative alternation speakers produce is affected (among other things) by semantic factors such as the animacy of the recipient and theme, as well as pragmatic factors such as givenness (Bresnan, Cueni, Nikitina, & Baayen, 2007). For example, an inanimate recipient will often lead to a prepositional dative construction ("bring more jobs and more federal spending *to their little area*").

These findings raise two developmental questions: do children show sensitivity to linguistic probability in their own syntactic choices, and if so, are those probabilities driven by the same factors that affect adult

production? Put differently, we can ask if children rely on the same multiple sources of information as adults in choosing between syntactic variants, and if their choices parallel the ones found in the speech directed to them. To become competent adult speakers, children need to integrate information from multiple sources: they have to attend to numerous cues, and be able to determine how they align with specific syntactic realisations. Through attending to adult uses, children need to pick up on the dimensions influencing syntactic choices, and draw on similar factors in their own productions. By looking at the syntactic choices of children and their caretakers we can examine when and how they develop these abilities.

Many studies have documented children's early sensitivity to distributional patterns at various levels of linguistic analysis, and their use of such information in language learning (e.g., Saffran, Aslin, & Newport, 1996; Swingley & Aslin, 2002). For example, infants can use transitional probabilities to break into the speech stream (e.g., Saffran et al., 1996) while slightly older children can use information about the kinds of subjects verbs take (e.g., animate vs. inanimate) to make syntactic generalisations (e.g., Goodman, McDonough, & Brown, 1998). In sum, children can (and do) make use of distributional information in a variety of ways as they are learning to talk.

Children are also sensitive to specific ways their caretakers talk. For instance, the proportion of correctly inverted questions in a child's speech is related to the frequency of such questions (as opposed to non-inverted ones like "you want to go?") in their caretakers' speech (Estigarribia, 2010). Similarly, the amount of *me-to-I* errors in children's speech (saying things such as "me do it") is correlated with the use of complex utterances like "Let me do it" in their input (Kirjavainen, Theakston, & Lieven, 2009). Such correlations between children's output and the input they hear are commonly found in language acquisition research (see Diessel, 2007 for a review).

While there is much research showing that children are sensitive to co-occurrence patterns in language, fewer studies have looked at how children learn linguistic variation, that is, how they develop sensitivity to the linguistic probability of alternating constructions in cases where there is more than one possible form. In their own productions, children seem to replicate the variation in linguistic features present in the speech directed to them (Foulkes, Docherty, & Watt, 2005; Smith, Durham, & Fortune, 2007, 2009). For example, the variable use of singular verbs with plural subjects ("Your leggies are cold. Your feeties is cold as well, aren't they?") occurring in a Northern Scottish dialect is acquired early by children and at rates matching the frequencies of caregiver input (Smith et al., 2007). However, other studies using artificial language learning paradigms suggest that children maximise high frequency variants instead of matching the distribution in their input:

when one item occurs in two different forms in the input, children regularise and tend to adopt the dominant pattern (Hudson Kam & Newport, 2005; Ramscar & Gitcho, 2007).

In this paper we focus on children's production choices as a way to explore if and when they become sensitive to linguistic probabilities of syntactic constructions. We look at the factors that guide children's production of the dative alternation in English to ask three related questions. The first is whether children's syntactic choices are influenced by the same factors that influence adults' choices: do they rely on similar information to choose between two possible variants? The second is whether children's syntactic choices, like those of adults, are influenced by multiple factors simultaneously, including semantic and pragmatic ones. The third has to do with the relation between children's input and output: do children assign the same weight to various factors as their caretakers? Such a finding would be consistent with the fact that as in other domains, children pay attention to complex distributional patterns from early on, and would be in line with the idea that children's learning of variation in language is supported by their sensitivity to distributions in their input.

We address these questions by conducting a multi-variable analysis of children's syntactic choices in the dative alternation. Studies show that adult production is sensitive to multiple variables, including both discourse and grammatical variables (see representative studies by Bresnan et al., 2007; Hinrichs & Szmrecsányi, 2007; Jaeger, 2006; Szmrecsányi, 2005). In contrast, most studies of children's production draw on experimental manipulations or corpus studies where the focus is on one variable (animacy, frequency, see i.a., Drenhaus & Féry, 2008; Snedeker & Trueswell, 2004). They demonstrate the range of factors that children are sensitive to, but do not investigate how and whether the different factors interact, or whether their effect is quantitatively different in children and adults.

Previous work on 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 that express roughly the same message. 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).

0. I showed some tricks to my Daddy. (NP PP)
0. 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., Collins, 1995; Gries, 2003; Snyder, 2003; Thompson, 1990). More recently, Bresnan et al. (2007) proposed a model showing that the effects of discourse accessibility, animacy, definiteness, pronominality, and syntactic weight are each significant variables influencing adult dative construction choice. Probabilistic variation in adult production of the dative alternation has been found both by corpus studies (Arnold, Wasow, Losongco, & Ginstrom, 2000; Bresnan et al., 2007; Collins, 1995; Thompson, 1990) and by controlled psycholinguistic experiments (Bock, 1982, 1986; Bock & Irwin, 1980; Bock, Loebell, & Morey, 1992; Bock & Warren, 1985; Branigan, Pickering, & Tanaka, 2008; McDonald, Bock, & Kelly, 1993; Pickering, Branigan, & McLean, 2002; Prat-Sala & Branigan, 2000; Stallings, MacDonald, & O'Seaghdha, 1998).

The studies of these syntactic alternations reveal a robust pattern of *quantitative harmonic alignment*, schematised in Figure 1.[1] What this means in the case of the dative alternation is that the choice of construction tends to be made in such a way as to place the inanimate, indefinite, nominal, or longer/heavier argument in the final complement position, and conversely to place the animate, definite, pronominal, or shorter argument in the position next to the verb where it precedes the other complement. For example, if the recipient argument is a lexical noun phrase, inanimate, indefinite, or longer, it will tend to appear in the prepositional dative construction; see the bolded recipient in (2a,b). Conversely, if the theme argument is a non-pronoun, inanimate, indefinite, or longer, it will tend to appear in the double object construction; see the bolded theme (3a,b).

1. give those to **a man** (more probable)
2. give **a man** those (less probable)
3. give **a backpack** to me (less probable)
4. give me **a backpack** (more probable)

[1] The term *harmonic alignment*, from Optimality Theory (OT) (Aissen, 1999; Prince & Smolensky, 1993), is used here phenomenologically to refer to the tendency for linguistic elements which are more or less prominent on a scale (such as the animacy or nominal expression type scales) to be disproportionately distributed in respectively more or less prominent syntactic positions (such as preceding in word order or occupying a superordinate syntactic position). See Bresnan & Nikitina (2009) for a stochastic OT analysis of the dative alternation employing formal harmonic alignment.

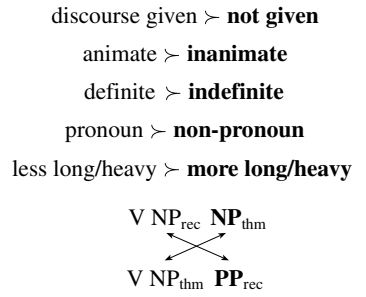

Figure 1. Qualitative view of quantitative harmonic alignment.

The dative alternation is also suitable for exploring child production: it is frequently used by children and robustly attested in child-directed speech (Campbell & Tomasello, 2001; Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989; Snyder & Stromswold, 1997). In previous work on the acquisition of the dative alternation, major issues have been the role of verb and event semantics, verb morphology, input verb frequency, and the order of acquisition of dative constructions (Campbell & Tomasello, 2001; Conwell & Demuth, 2007; Fisher, Hall, Rakowitz, & Gleitman, 1994; Goldberg, Casenhiser, & Sethuraman, 2005; Gropen et al., 1989; Mazurkewich & White, 1984; Osgood & Zehler, 1981; Viau, 2007), as well as structural persistence (Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007; Thothathiri & Snedeker, 2008). One study has focused on properties of the theme and recipient arguments, including heaviness, givenness, and animacy (Snyder, 2003), but provides descriptive statistics rather than a probabilistic model.

Previous work demonstrates the range of factors that children are sensitive to but does not provide a way to assess their weight relative to one another, or relative to the same factors in adult speech. It is also not yet known (1) whether the same quantitative harmonic alignment patterns in datives used in conversations between adults appear in child-directed speech, and (2) whether children replicate the probabilistic syntactic patterns of the dative alternation in their own spontaneous speech in ecologically natural settings. In our investigation we draw on previous developmental and psycholinguistic research on the dative alternation to explore the similarities and differences in how various variables affect child and adult production. In particular, we want to compare the way the same factors affect child and child-directed speech. Our investigation is not meant to uncover the exhaustive set of variables governing child production, but instead provides a way of comparing the effect of various factors on child and adult speech. First, we develop a probabilistic 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 because 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)], it is important to see what children's actual input looks like. 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.

Probabilistic models

Our statistical methods employ probabilistic modelling using logistic mixed-effect multiple regression models of the input (child-directed speech) and output (child speech). Logistic regression modelling is advantageous because it has the power to evaluate independent contributions from multiple predictors while simultaneously evaluating the joint contribution of specific predictor combinations. The models yield information about the relative strength of each predictor over and beyond the rest. Such models are becoming increasingly popular for modelling the probability of a particular outcome in language production given a set of potentially interacting linguistic variables (Baayen, 2008; Forster & Masson, 2008; Johnson, 2008). Logistic regression is appropriate for investigating the binary outcomes of alternation behaviour, as has been demonstrated by previous studies on the genitive alternation (Hinrichs & Szmrecsányi, 2007; Shih, Grafmiller, Futrell, & Bresnan, 2009), the dative alternation (Bresnan et al., 2007), the active/passive voice alternation (Weiner & Labov, 1983), and the presence/absence of a complementiser (Jaeger, 2010; Roland, Elman, & Ferreira, 2006).

Formally, logistic regression uses the function in the equation below to describe the relationship between a set of variables, $X=x_1, x_2, \ldots, x_n$, and the probability of an outcome given the relative weight of each value:

$$f(z) = 1/(1+e^{-z}) \quad \text{where } z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \mu_i$$

In this equation, the weight of each variable, x_i, is represented by the parameter β_i. The probability of a particular outcome is simply the output of the function, $f(z)$. In the case where all variables are null, the intercept (β_0) alone determines the outcome probability. The unknown parameters are set by maximum likelihood estimation for each variable over all instances in the input. We also include random error terms, μ_i, to adjust for normal speaker variation where appropriate, as defined for mixed-effect logistic models.

APPLICATION: MODELLING THE DATIVE ALTERNATION IN CHILD PRODUCTION

To assess whether the probabilistic predictors pertinent to adult production play a role in child production, we analyse the children's dative utterances with a mixed-effect logistic regression model using the variables from the Bresnan et al. (2007) model. Regression models assume that each observation for analysis is independent, which is manifestly untrue when multiple observations are collected from individual speakers as in the dataset we constructed. By conditioning the regression on the random effects of speaker, however, mixed-effect regression models appropriately capture the speaker-dependent clustering of observations.

Bresnan et al. (2007) present a statistical model using mixed-effect logistic regression modelling of the production of dative sentences by adults. The study is based on spoken language, with 2360 dative observations culled from the three million word Switchboard collection of recorded telephone conversations (Godfrey, Holliman, & McDaniel, 1992). They show how the alternation is affected by multiple variables, many of which were proposed in previous studies (e.g., Goldberg, 1995; Green, 1974; Oehrle, 1976; Pinker, 1989). The mixed-effect model we employ controls for the fact that children are known to vary widely in their individual developmental trajectories (Bates, Dale, & Thal, 1995; Clark, 2003), and allows us to generalise 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.

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 (Brown, 1973; Clark, 1978; Demetras, 1989a; Kuczaj, 1977; Suppes, 1974). 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 the children's production between the ages of 2–5 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 distribution for each child.

We selected only dative constructions following the "verb NP NP" (double object construction) or "verb NP PP" (prepositional dative)

TABLE 1
Number of dative utterances by child

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

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). We removed the data points where the theme and the recipient did not occur postverbally, i.e., in instances of topicalisation, question formation, or passivisation. 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 show it to my + . . ." [Adam, 4;2.17]), all the others we eliminated did not have any recipient at all.

For the NP PP datives, 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 the same as the ones used in the adult model of Bresnan et al. (2007), excluding variables that are not relevant for the two verbs we analyse such as semantic class of the verb.

Animacy of themes and recipients

Adult production experiments have demonstrated that syntactic choices between alternatives are sensitive to animacy (Bock et al., 1992). Moreover, the sensitivity to animacy is independent of other factors such as weight (Bresnan et al., 2007; 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 English (e.g., Thompson, 1990).

Children from around the age of two 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). Toys, however, did not differ significantly from inanimates in their effect on construction choice, and therefore the animacy variable only takes into account the opposition between true animates and inanimates in our investigations.

Length of themes and recipient

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 (Behaghel, 1909; Bresnan et al., 2007; Wasow, 2002). 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"). We measured this factor in terms of the number of words. 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, the 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.

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 (Bresnan, 2007; Bresnan et al., 2007; Bresnan & Nikitina, 2009; Collins, 1995; Green, 1971, 1974). In adult data, pronominal recipients tend to appear first in a NP NP construction ("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 is very likely 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*, e.g., "I if if I gave you some, you I will gwab [:grab] it away" [Trevor, 2;8.10]) were categorised as lexical (non-pronouns).

Givenness

A number of authors have shown the importance of information structure in dative constructions: given information typically comes before new information (Arnold et al., 2000; Bock & Irwin, 1980; Bresnan et al., 2007; Collins, 1995; Erteschik-Shir, 1979; Givón, 1984; Givón, 1988; Halliday, 1967, 1970; Ozón, 2006; Primus, 1998; Ransom, 1979; Rappaport Hovav & Levin 2008; Smyth, Prideaux, & Hogan, 1979; Snyder, 2003; Thompson, 1990; Waryas & Stremel, 1974; Wasow, 2002). 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 Gundel, Hedberg, & Zacharsky (1993) and Prince (1981). 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*) are coded as given.

Syntactic 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). Szmrecsányi (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 syntactic parallelism plays a role for passive.

Syntactic priming effects have also been reported in young children in experimental settings (see Bencini & Valian, 2008; Conwell & Demuth, 2007;

Huttenlocher, Vasilyeva, & Shimpi, 2004; Savage, Lieven, Theakston, & Tomasello, 2003; and references therein). These findings have been central to the debate about the abstractness of children's early representations. Priming is seen as a way of assessing children's syntactic knowledge: if children show priming of a construction (independent of lexical similarity), they have developed a more abstract representation of that construction. Interestingly, there have been no studies to date that investigate structural persistence in children using corpus data where one explores the effect of priming while controlling for other factors (like givenness or animacy).

We coded the structural persistence factor in the following way. We examined the 10 previous turns in the conversation for the most recent dative construction used, if any: when one was found, we marked the choice of construction used and the speaker of that dative utterance (adult vs. child). We also counted the distance of the previous utterance from the current dative construction by the number of clauses. In order to distinguish a structural persistence effect from one that is merely driven by verbatim repetition, we distinguished between utterances that were an exact repetition of the previous dative from ones that were not. There is not enough variation in the data to test either for a lexical boost of priming (Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008) or for a verb-general priming effect.

Age and mean length of utterance (MLU)

We consider it likely that some of our measures could be confounded with developmental advances allowing children to produce more complex utterances overall (e.g., length of theme/recipient). 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 in predicting children's syntactic choices.

Resulting model and discussion

The final logistic regression model for the children's dative alternation is summarised in the formula in Table 2. We constructed the model in R (R Development Core Team, 2009) 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,

TABLE 2
The model formula

Probability(*Response* = *NP PP*|X, μ_i) = $1/(1 + e^{-(X\beta + \mu_i)})$ *where:*		
$X\ \beta =$	-1.3726	+
	$-0.5767 \times$ the number of words in the theme	+
	$1.0106 \times$ the number of words in the recipient	+
	$3.1265 \times$ nominal expression type of the theme = pronoun	+
	$-1.4432 \times$ nominal expression type of the recipient = pronoun	+
	$-1.7097 \times$ previous NP NP construction in the last ten turns = yes	+
	$2.3123 \times$ previous NP PP construction in the last ten turns = yes	+
	$-1.9161 \times$ (interaction between pronominality and givenness)	+
	$0.1389 \times$ givenness of the theme = new	
$\mu_I \sim N(0, 0.25)$		

and stopping when the elimination of a variable would significantly reduce the model fit. Five variables turn 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 effect of persistence remains significant when we control for repetition: it is not driven solely by instances of verbatim repetition. We also find one interaction between pronominality and givenness of the theme. The other variables—age and animacy—lack predictive value and were eliminated from the final model. We also verified that there was no collinearity between the variables.

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 β in the formula (see Table 2). The intercept gives the likelihood of the prepositional construction for the reference values of the variables. The model also accounts for variation between different speakers (random variable μ_i where i ranges over the speakers), assuming a normal distribution of this variance. The magnitude and the direction of the influence of each variable are given by the coefficients, which are in units of log odds in the model space. Any positive value for a coefficient in the formula increases the likelihood of the prepositional construction. For example, the length of the recipient and the nominal expression type of the theme have positive coefficient values: they increase the odds of the NP PP construction. Conversely, any negative value for a coefficient decreases the likelihood of the prepositional construction. For example, the values of the coefficient of the previous NP NP construction and the length of the theme are negative: they decrease the odds of realising a NP PP construction. The coefficients can be transformed into odds ratios, which indicate the relative probabilities that one of the two outcomes will occur (in our model, the designated outcome is the NP PP

construction). The odds ratios take values between 0 and ∞. Values greater than 1 favour the outcome, and the more they exceed 1, the more they favour it. On the other hand, values smaller than 1 disfavour the outcome, and the closer they are to zero, the more they disfavour it. For example, the prepositional construction is $e^{3.1265} = 22.8$ times more likely when the theme is a pronoun. The relative odds of each variable can be seen in Table 3, as well as the detailed *p*-values and confidence intervals.

One diagnosis for assessing the quality of the model is the C statistic: 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 discriminative capacity (Harrell, 2001). For our model, C is 89.7%. Another way of assessing the quality of the model is to get classification accuracy on unseen data: this checks that the model is not overfitted to the data it was trained on. To verify that the model generalises satisfactorily beyond the data it was trained on, we collected dative utterances of the verb *bring* for Adam and Sarah, as well as utterances of the verbs *give*, *show*, and *bring* for two other children, Eve and Jimmy (Brown, 1973; Demetras 1989b). This yielded 57 new utterances, which amounts to 10% of the training data, and is sufficient for testing purposes. Contrary to the verb *give* and *show* which favour the double object construction, *bring* has a balanced distribution. In the test set, 24 utterances contain the verb *bring*, half in the NP NP construction, half in the NP PP construction. The classification accuracy on the test set is quite high: 91.2%, which is a statistically significant improvement ($p < .01$) over a baseline of always choosing the most frequent construction (68.4%). The five erroneous predictions involve the verb *bring*. When restricting the test set to the verb *bring*, the model achieves a reasonable classification accuracy: 79.2%. It is a statistically significant improvement ($p < .01$) over the 50%

TABLE 3
Odds, *p*-values, and confidence intervals of the significant main effects and interaction in the child model

Main effects	*Odds*	*p-Value*	*95% Confidence interval*
Theme type = pronoun	22.80	.0000	9.83–53.83
Recipient type = pronoun	0.24	.0000	0.12–0.48
Theme length	0.56	.0246	0.34–0.93
Recipient length	2.75	.0118	1.25–6.03
Previous dative = NP	0.18	.0000	0.08–0.41
Previous dative = PP	10.10	.0000	3.66–27.88
Theme type = pronoun × theme givenness = new	0.15	.0101	0.03–0.64

baseline for *bring*. This demonstrates that the model is not overfitted to the data and generalises to data from unseen datives and other children.

The model delivers not only information about which variables are significant, but also about the strength of their predictive power measured in terms of log odds. The model predictions for all significant variables are shown in Figure 2.

Length

As in the adult data, length is a significant predictor. Long themes tend to 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 involves a short theme:

(d) I wanna give *that* to Poy now [Nina, 2;9.26]
(e) that gorilla's giving *bananas* to them [Nina, 3;1.6]

The relationship between length of arguments and construction choice can be seen in the upper part of Figure 2: the probability of occurrence of the prepositional dative decreases when the length of the theme increases (upper right corner). The inverse occurs for recipient length: the probability of the prepositional dative increases as length increases.

Pronominality

Pronominality of theme and recipient also influences children's 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]. Prepositional datives are more likely when the theme is realised as a pronoun, and less likely when the theme is realised as a lexical NP; conversely, if the recipient is realised as a pronoun, prepositional datives are less likely than if the recipient is realised as a lexical NP (centre of Figure 2). Again, this is similar to what we see in adult production. Looking at length and pronominality together, we can see harmonic alignment effects similar to those found in the Bresnan model: shorter and more prominent NPs (pronominal) align with the first syntactic position while longer and less prominent ones (non-pronominal) align with the second position.

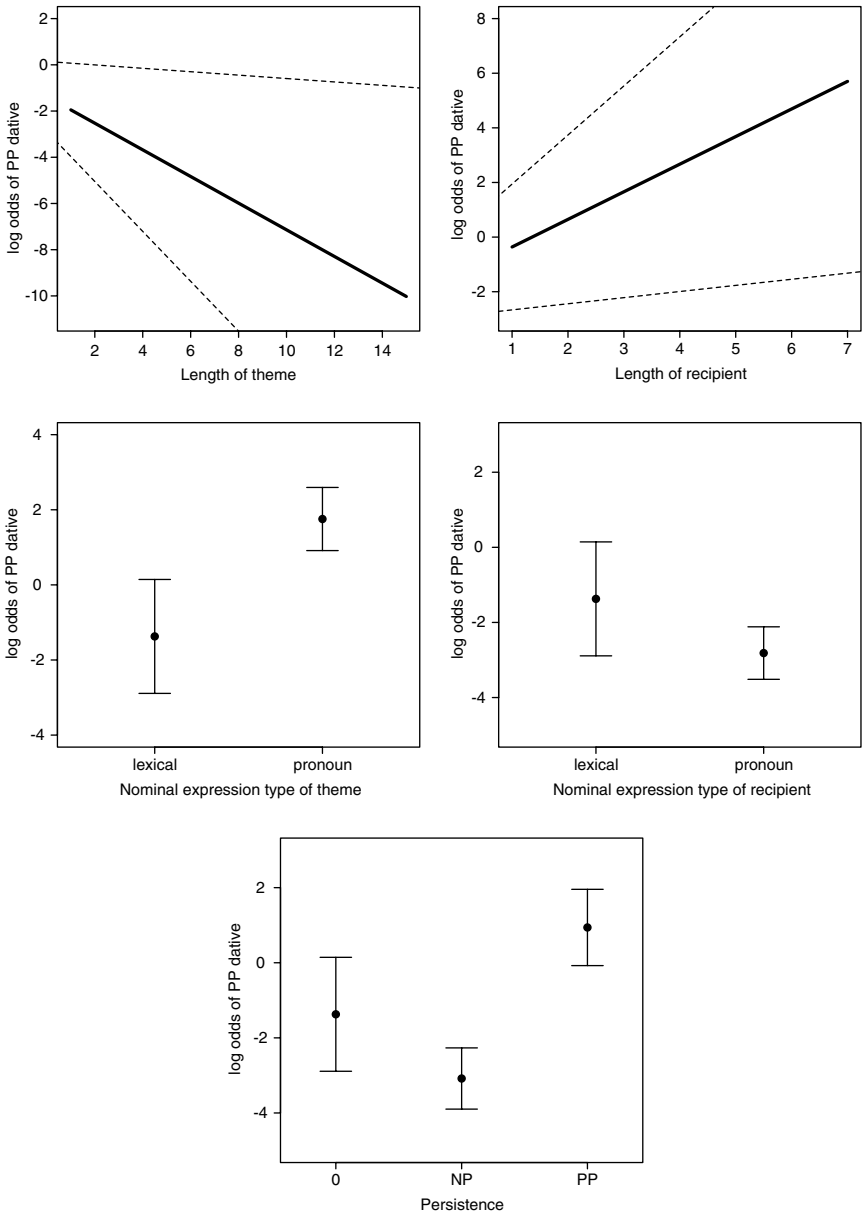

Figure 2. Log odds of prepositional dative given the main effects.

Syntactic persistence

As in the adult model, syntactic persistence plays a role. Children tend to reuse a construction previously heard. Importantly, only 25% of these uses are exact repetitions of the previous dative construction:

[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*.

The other 75% diverge from the previous use in the choice of lexical items or verb. Children are not just repeating utterances but instead are presumably influenced by the previous construction type in creating new utterances.

[Abe, 2;8.6]

MOT: show it to Mike.
CHI: give this to me Dad.

[Nina, 2;9.21]

MOT: do you think you could give me a cup of tea?
CHI: ok, I will give you some more tea and sugar and milk.

The effect of persistence can be seen in the bottom of Figure 2. The previous dative influences the current one. If there was a previous dative, and it was a prepositional one (NP PP), the current construction is more likely to be a prepositional dative. Conversely, if a double object construction was previously produced (NP NP), the current construction is less likely to be a prepositional dative. This is in line with previous reports of priming in child production that were obtained using experimental methods (Branigan, Pickering, Liversedge, Stewart, & Urbac, 1995; Huttenlocher et al., 2004; Savage et al., 2003). The current findings offer further support for the effects of syntactic persistence on children of a very young age and in naturalistic settings while controlling for exact repetition. It is of interest that there is no interaction with age: children are more likely to produce a prepositional dative following a similar dative regardless of age. That is, they show sensitivity to construction type early on. Also, since we control for repetition,

we can be sure that what we see is an effect of construction type, and not merely verbatim repetition.

Animacy

Contrary to our expectations, animacy is not 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 (86.3% in the double object construction—352 out of 408 utterances, 91.8% in the prepositional dative construction—112 out of 122 utterances). Given the semantics of the verbs, this distribution is not surprising: one usually gives or shows something to *someone*.[2]

Givenness

Givenness is also not a significant factor as a main effect. However, there is a highly significant interaction between givenness and pronominality: a theme is significantly less likely to occur in a prepositional construction when it is both pronominal and refers to a new, not previously mentioned, referent. In this condition the theme is significantly more likely to occur in the double object construction, where it is in final position, consistent with quantitative harmonic alignment (Figure 1). In contrast, givenness plays no role at all when we re-run the model on the child data excluding pronominal themes and recipients. Excluding the pronominal themes and recipients yields a small number of datives, but the distribution in givenness is well-balanced: for the NP NP construction, 25 themes are given and 20 are new, 21 recipients are given and 24 are new; for the NP PP construction, seven themes are given and eight are new, nine recipients are new and six are given. A related finding is reported in a production experiment by Stephens (2010, p. 169) where children positioned recipients first only if they were both given and pronominal. Thus, children do show the harmonic alignment effects of givenness in choosing alternative dative constructions, but the effects may be restricted to pronoun arguments.

[2] 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).

Since given arguments are likely to be shorter, requiring less descriptive elaboration to establish a common ground for referring, it is important to examine whether its potential effects on lexical arguments might be masked by collinearity with length. To this end we de-correlated givenness from pronominality and length: the model takes into account what is left of givenness after removing what is captured by pronominality and length. The givenness residual does not provide a significant contribution. As in Stephens (2010, p. 169), the tendency to place the given theme before the recipient (by choosing the prepositional dative) was not significant for lexical themes. In children's dative productions, in contrast to that of adults, givenness may exert its effect on construction choice indirectly through the use of pronouns.

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 3–7, the magnitude of the responses varies by child, but the model informs us that this variation is not significant: the intercept adjustments by child are all zero, meaning that there is no significant variation by child. Moreover, as the graphs show (Figures 3–7), 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 where the lines are non-parametric 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.

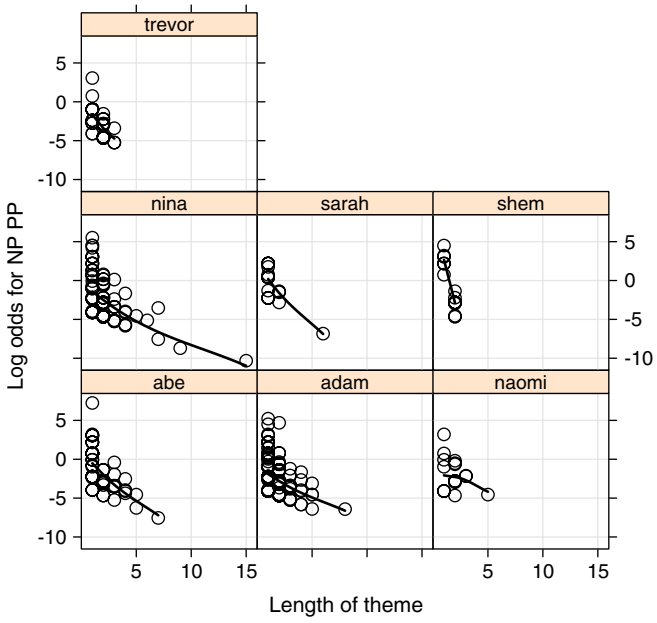

Figure 3. Effects of the length of the theme by child.

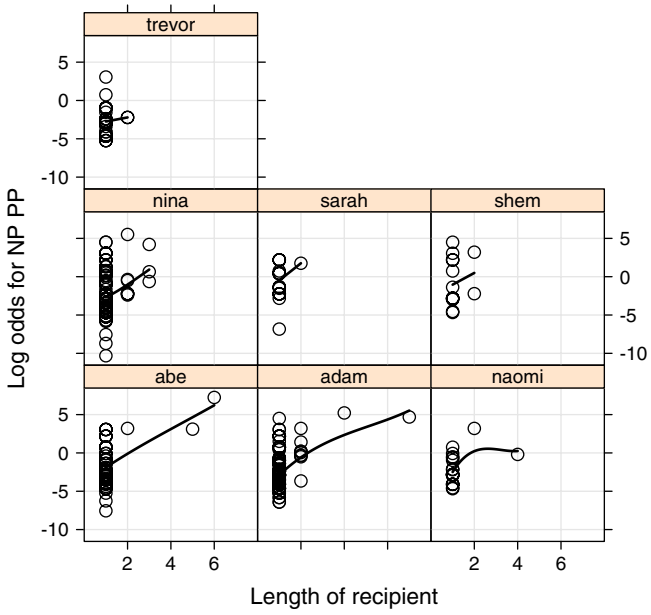

Figure 4. Effects of the length of the recipient by child.

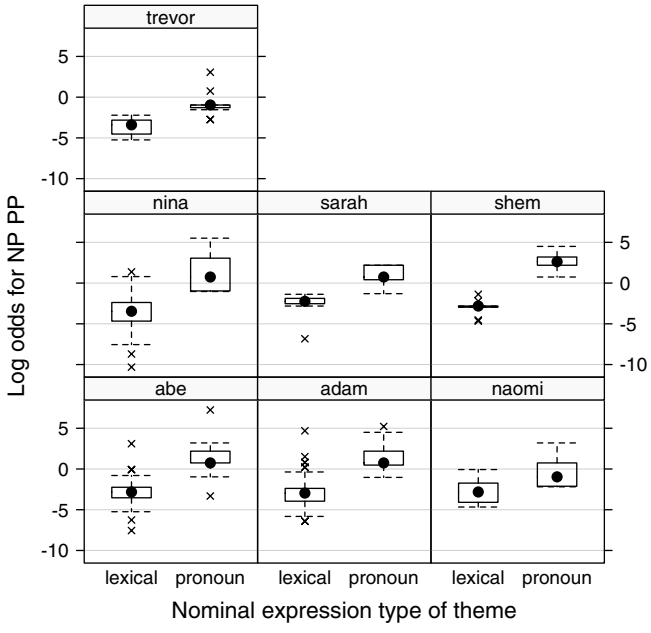

Figure 5. Effects of the theme nominal expression by child.

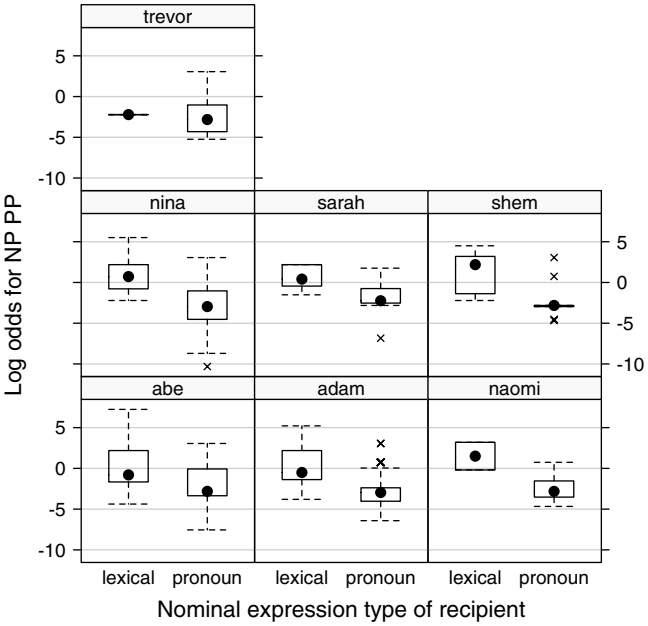

Figure 6. Effects of the recipient nominal expression by child.

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.

We see, then, that children produce alternating forms early on (consistent with Campbell and Tomasello, 2001) and that construction choice in child production is governed by multiple variables. In particular we find that (1) the probabilistic harmonic alignment pattern of adult dative productions (Figure 1) is robustly replicated in children's dative productions across the entire sample from CHILDES, and (2) these probabilistic patterns are also replicated by individual children. We also find that the influence of discourse givenness on children's construction choices differs from that of the adults in the Bresnan et al. (2007) study: with the children, the givenness effects are reliable only in their use of pronouns. Previous work has shown that the use of pronouns differs across genres (Biber and Finegan, 1989), hence this difference in our model of children's dative productions could possibly reflect the different discourse pragmatics of the face-to-face conversations sampled in our CHILDES data and the data sampled from remote telephone conversations between adult strangers in the Bresnan et al. (2007) study. This issue will be investigated when we turn next to the relation between the probabilistic patterns in the children's output and their input from child-directed speech.

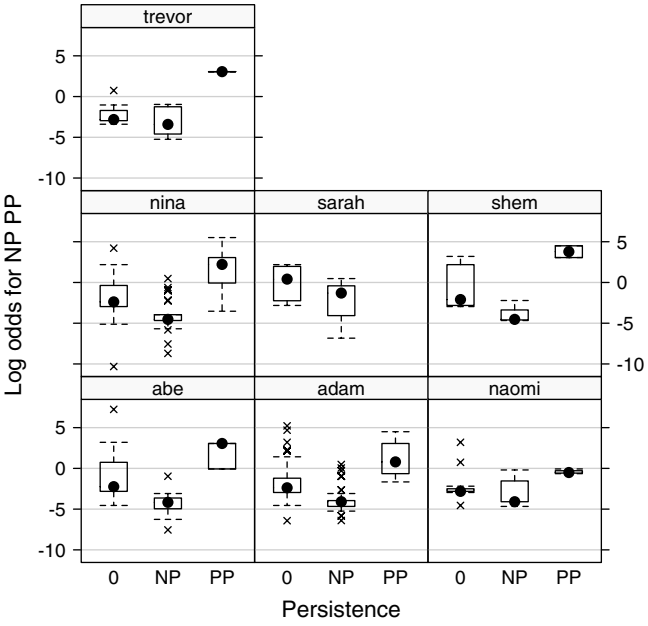

Figure 7. Effects of persistence by child.

COMPARISON WITH CHILD-DIRECTED SPEECH

By comparing children's production with the production of their caretakers, we can 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.

Modelling 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 the children. We collected the adult dative constructions starting from the files that yielded the most datives until we had a sample size of child-directed datives comparable to that of the child datives. This resulted in child-directed speech data from three of the children studied in the previous section: Adam, Nina, and Shem. We limited our data to this sample to facilitate statistical comparisons. If we had included all of the child-directed datives, the adult sample would have been more than double the size of the child sample making the statistical model weighted towards the adult sample. All of the caretakers produced both types of datives. 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 we coded the variables following the procedure previously outlined.

The dialogues typically had one primary adult interlocutor, but there were occasionally other adult speakers interacting with the child. Adult speakers who had fewer than 10 utterances were removed, yielding five different speakers for the three children. Table 4 shows the number of speaker utterances according to the child participating in the dialogues.

We applied the same modelling 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 reliable main effects in the child data (pronominality of the theme and the recipient, length of the theme and the recipient, and persistence) are also reliable in the child-directed model, and the directions of the effects are the same.

As in the case of the children, animacy is not significant in the child-directed model—again this is probably due to the semantics of the verbs: most recipients in both constructions are animate (92.2% in the double object construction—539 animate recipients out of 584, 93.6% in the prepositional construction—191 out of 204).

In contrast to our findings for children's speech, givenness is a marginally reliable factor for the adults speaking to the children: when a lexical theme is new to the discourse the likelihood of a prepositional dative is reduced compared to a given lexical theme ($p < .08$); a new pronoun theme further reduces this likelihood ($p < .06$). These findings remained when we de-correlated givenness from both pronominality and length to remove potential masking effects of these possibly correlated variables.

In sum, the children's output model may be described as similar to the input model of child-directed speech, but reduced in dimensionality. The trending influence of theme givenness as a main effect on dative construction choice in the input is lacking in the output. However, children do show a

TABLE 4
Number of dative constructions uttered by the children's caretakers

		Number of adult dative utterances		
Child	*Caretaker*	*NP NP*	*NP PP*	*Total*
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
Totals		584	204	788

TABLE 5
Odds, *p*-values, and confidence intervals of the significant main effects and interaction in the child-directed speech model

Main effects	*Odds*	*p-Value*	*95% Confidence interval*
Intercept	2.01	.3770	0.66–5.42
Theme type = pronoun	126.15	.0000	40.15–396.37
Recipient type = pronoun	0.06	.0000	0.03–0.15
Theme length	0.26	.0000	0.14–0.47
Recipient length	2.59	.0024	1.40–4.79
Previous dative = NP	0.31	.0106	0.13–0.76
Previous dative = PP	12.3	.0003	3.11–48.62
Theme givenness = new	0.50	.0762	0.23–1.08
Theme type = pronoun × theme givenness = new	0.10	.0510	0.01–1.01

similar systematic givenness effect when using pronoun theme arguments: pronouns referring to new theme entities are more likely to appear in double object constructions than pronouns referring to given theme entities. The marginal reliability of givenness on lexical themes in the input suggests that children are initially learning only the most informative predictors of dative construction choice (McElvain, 2010).

The estimates of the variables, as well as the model intercept, are given in terms of odds ratios in Table 5. The classification accuracy of the model is very high: 94.5% (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 6. These adjustments represent the adult's individual bias towards the prepositional dative construction: they quantify by how much the intercept (which gives the likelihood of the prepositional construction for the reference values of the variables) has to be modified for each adult.

TABLE 6
Intercept adjustments for each adult in the mixed-effect model for child-directed speech

Child interlocutor	*Adult speaker*	*Intercept adjustment*
Adam	Caretaker 1	−0.182
	Caretaker 2	0.072
Nina	Caretaker 1	0.486
Shem	Caretaker 1	−0.367
	Caretaker 2	0.005

Conjoined model and discussion

To test the differences in the models of child and child-directed speech production of dative sentences for significance, 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 model shows us whether the different variables work in different ways in the two populations.

Table 7 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 8. The conjoined mixed-effects regression model obtains a high classification accuracy (92.6% against a baseline of 75.3%). A C statistic of 95.6% reinforces the quality of the model.

The conjoined model shows that all of the effects shared between the separate models are significant but also reveals several significant differences between the input and output patterns. All the variables we looked at 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 favouring the prepositional dative, and for both a lexical recipient favours the prepositional dative construction as does a pronominal theme.

The child and adult populations differ in the sensitivity to the shared variables. The interaction effects for the length of the theme (Figure 8) as well as for the nominal expression type of the theme and the recipient in

TABLE 7
Odds and *p*-values of main effects and interactions in the conjoined model

Main effects	*Odds*	*p-Value*	*95% Confidence interval*
Intercept	1.99	.333	0.49–8.12
Group = child	0.17	.038	0.03–0.91
Theme type = pronoun	124.96	.0000	43.10–362.30
Recipient type = pronoun	0.07	.0000	0.03–0.15
Theme length	0.26	.0000	0.14–0.45
Recipient length	2.50	.0000	1.57–3.98
Previous dative = NP	0.23	.0000	0.13–0.41
Previous dative = PP	10.38	.0000	4.57–23.54
Theme givenness = new	0.71	.2415	0.41–1.25
Theme type = pronoun × theme givenness = new	0.19	.0071	0.05–0.63
Group = child × recipient type = pronoun	3.19	.0282	1.13–8.97
Group = child × theme type = pronoun	0.15	.0025	0.04–0.51
Group = child × theme length	2.22	.0382	1.04–4.74

TABLE 8
Intercept adjustments for each speaker in the mixed-effect model for both adult and child data

Speaker	*Intercept adjustment*
Abe	0.038
Adam	−0.082
Naomi	−0.102
Nina	0.222
Sarah	−0.106
Shem	0.184
Trevor	−0.140
Adam caretaker 1	−0.169
Adam caretaker 2	0.033
Nina caretaker 1	0.386
Shem caretaker 1	−0.241
Shem caretaker 2	0.000

predicting the NP PP construction (Figure 9) show that the directions of the effects are the same, but that children and adults differ in the degree to which the variable influences their choice. Longer themes are avoided by both the children and the adults in the medial position provided by the NP PP construction, but the adults' avoidance is more complete, producing a steeper fall off in the odds of a prepositional dative as the theme grows longer. In a similar way, the nominal expression type of the recipient and

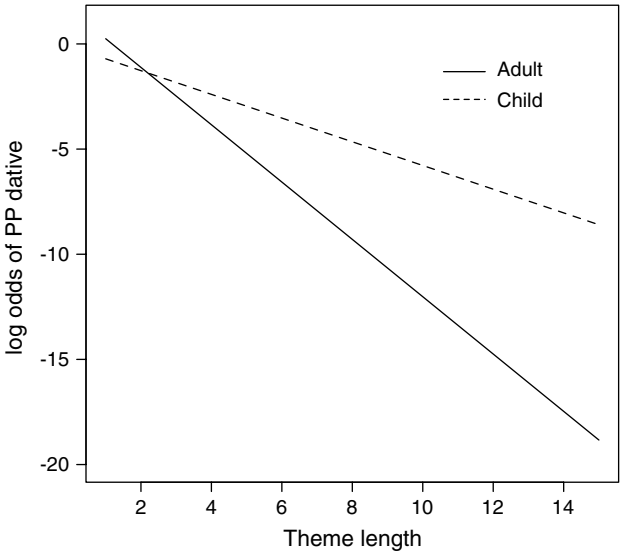

Figure 8. Interaction effect for length of theme.

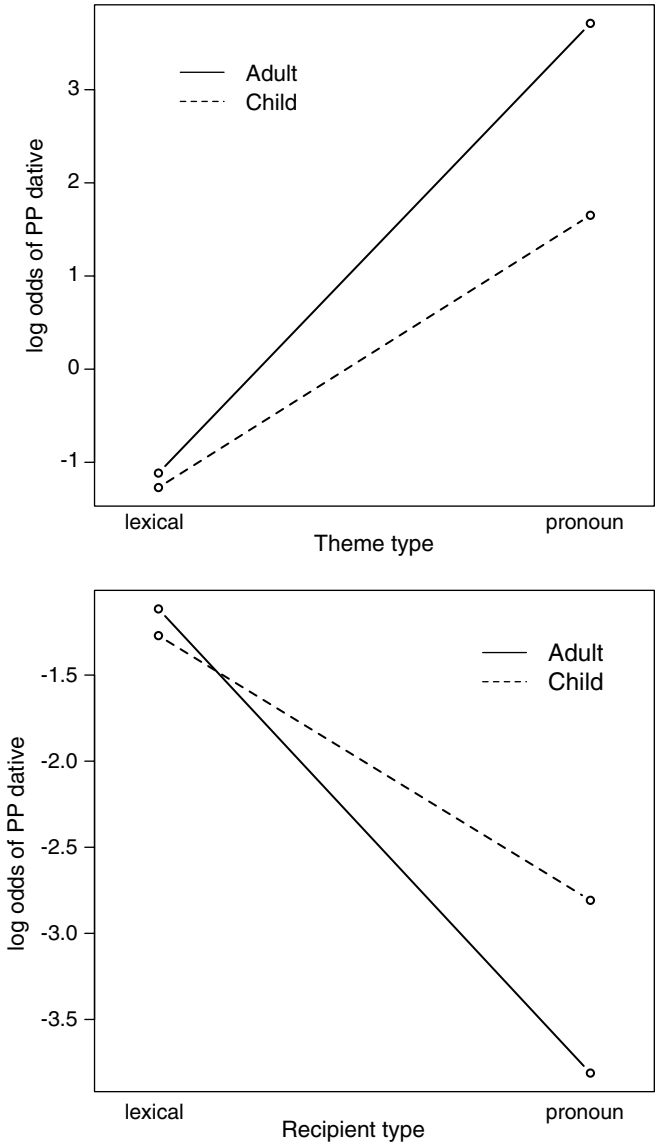

Figure 9. Interaction effects for nominal expression type of theme and recipient.

theme has a greater influence on the adults' production choice, as indicated by the steeper slope of the lines representing the effect of pronominality in the adult data (solid lines) compared to the child data (dashed 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

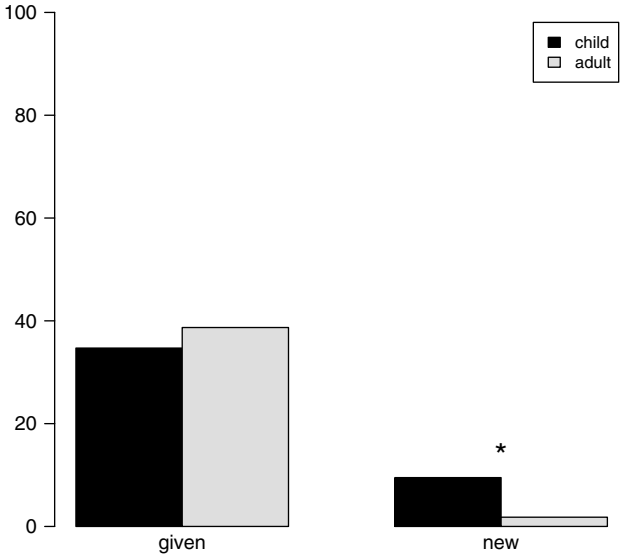

Figure 10. Proportions of pronominal forms in new and given themes for children and adults.

even when the NP is pronominal ("gave her it"); however, this dispreference is gradient and variable across speakers, as discussed in Bresnan & Nikitina (2009). 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]).

It is possible that children use stressed pronouns more, which could make a pronoun more acceptable in final position. Other 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. It is also possible that such utterances reflect children's tendency to use frozen chunks which are very frequent ("give me"/"show me"/"give you"). Children's repeated use of such frequent bigrams may lead them to prefer realisations that build on those sequences: children would start with the frequent sequence, and add the theme to it. Further data from experiments could explore whether children accept such utterances when uttered by adults and shed light on this explanation. Whatever the reasons may be, the children's output manifests the same probabilistic patterns as their input, but less sharply.

The conjoined model fails to show a significant contrast between the children and adults in the influence of givenness on construction choice, possibly because the effect is small and only marginally reliable in our small child-directed speech dataset. But elsewhere our data provides evidence of 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 & Hendriks, 1999; Song & Fisher, 2007). We analysed the relation between givenness and pronominality in child and adult productions. Figure 10 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 use a similar proportion of pronouns for given entities [34.7% vs. 38.7%, $\chi^2 = 1.32$ ($N = 763$), $p = .14$], but children are 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 speculate that children are faced with a cue clash (Bates & MacWhinney, 1987): the pronominality of the theme pushes children towards a NP PP realisation, while its new discourse status pushes them towards a NP NP realisation. The effect of givenness on children's dative choices may be weakened 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 9) 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. To put it another way, children have the same probabilistic constraints on their output as adults, but they have not yet learned to weight or prioritise them in a way that fully converges with their adult models.

CONCLUSION

This paper has developed multi-variable models of child and adult production of the dative construction. The model demonstrates a strong similarity in the variables at play for both populations. We have found that probabilistic syntactic patterns of harmonic alignment in dative constructions used in adult-to-adult conversations also characterise adult conversations with young children, and that individual children replicate these probabilistic patterns in their own speech in ecologically natural settings. In particular, (1) children match the end-weight effects of adult speech

addressed to them by tending to choose dative constructions that place the heavier constituent later in the clause, (2) they match the preference for dative constructions in which pronoun arguments precede lexical arguments (even after adjusting for differences including length/weight), and (3) they match the greater likelihood of using dative constructions in which discourse given themes occur earlier and new themes later (but only within the restricted domain of pronouns). All of these patterns hold after adjusting for structural persistence and repetitions, as well as individual differences in preferences for dative constructions.

From these findings, we see that children mirror the adult production patterns in their input. Our results suggest that, for the dative construction, and for the variables we looked at, child speech only differs from the speech of their adult interlocutors in degree, not in kind. Some of the differences we found (e.g., in animacy) have more to do with what children talk about, than with a fundamental difference in their variable choices among syntactic alternatives. Other differences (e.g., in the sensitivity to predictors of pronominality and givenness) are compatible with the view that children start out over-weighing cues that are more reliable (Bates & MacWhinney, 1987; Trueswell, Papafragou, & Choi, 2008).

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, 2010; Goodluck, 2007; Trueswell, Sekerina, Hill, & Logrip, 1999). The findings we report are also in line with the idea of a usage-based continuity in the factors that influence production, one that is related to the speech children hear. Children's syntactic choices, like those of adults, were shown to be influenced by multiple factors from early on, and the weights assigned to these factors are similar to the ones assigned by the caretakers. Our results might stem from the fact that, as in other domains, children pay attention to complex distributional patterns from early on, and are consistent with a view of language learning in which attainment of adult-like competence is assisted by the sensitivity and attention to such complex distributional patterns. Some studies have shown evidence that children fare worse on probability matching tasks than adults (Hudson Kam & Newport, 2005; see discussion in Ramscar & Gitcho, 2007) and have suggested that children tend to maximise to the dominant pattern when different forms are present in their input. However 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 regularise and maximise to only one of the alternation's variants. The naturally occurring data considered here manifests an apparent sensitivity on the part of the children

to production probabilities: from early on, children are using both variants of the dative alternation and replicate subtle patterns found in their input.

This study suggests that the language 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 modelling 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 modelling methods.

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