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# Sources of Variability in Children's Language Growth

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## Abstract

The present longitudinal study examines the role of caregiver speech in language development, especially syntactic development, using 47 parent-child pairs of diverse SES background from 14 to 46 months. We assess the diversity (variety) of words and syntactic structures produced by caregivers and children. We use lagged correlations to examine language growth and its relation to caregiver speech. Results show substantial individual differences among children, and indicate that diversity of earlier caregiver speech significantly predicts corresponding diversity in later child speech. For vocabulary, earlier child speech also predicts later caregiver speech, suggesting mutual influence. However, for syntax, earlier child speech does *not* significantly predict later caregiver speech, suggesting a causal flow from caregiver to child. Finally, demographic factors, notably SES, are related to language growth, and are, at least partially, mediated by differences in caregiver speech, showing the pervasive influence of caregiver speech on language growth.

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The present paper concerns the relation of caregiver speech to child language development. A major issue for acquisition theories concerns the sources of language growth, especially for syntax. While all investigators recognize that exposure to incoming speech is essential for acquiring a language, different theories make alternative claims about the influence of input on child language. Constructivists argue that variations in input are critical to language outcomes in children (e.g., Aslin, Saffran and Newport, 1999; Gomez and Gerken, 1999; Saffran 2001; Saffran and Wilson, 2003; Tomasello 2000), whereas nativists argue that individual variations in input are less important: in their view, innate grammatical principles are the major determiners of children's language outcomes (e.g., Lidz, 2007; Lidz and Gleitman, 2004; Lidz and Waxman, 2004).

It has been difficult to establish the role of input because studies of the relation between caregiver and child speech typically are correlational, and results can be explained in a variety

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of ways. For example, while correlations might be driven by variations in input, they might instead reflect variations in the language ability of different children, which, in turn, affect how caregivers speak to them. Further, correlations between caregivers and children based on observations at a single time point might reflect temporary factors, such as particular topics of conversation during a single session.

Although we use correlational data in the present study to examine the role of input in language growth, we take steps to address some of the difficulties arising in earlier studies. We use lagged correlations across different observations (time points) to explore enduring relations between caregiver and child speech. Since our central question concerns the possible influence of caregiver speech on later child language, we are especially interested in lagged correlations where caregiver speech precedes child speech. If correlations between caregiver speech at an earlier time and child speech at a later time are much greater than those between child speech at an earlier time and later caregiver speech, it would suggest that caregiver input is a source of language growth, thus supporting a constructivist account of acquisition.

Much of the current empirical support for a constructivist view involves studies using quantitative measures of input, i.e., of the amount of speech individual caregivers produce (e.g., Hart and Risley, 1995; Huttenlocher, Haight, Bryk, Selzer, and Lyons, 1991). However, these measures are limited because they do not differentiate repeated use of the same elements from use of different elements. The present study incorporates a more theoretically relevant measure of input, namely the diversity of the speech of individual caregivers, i.e., the variety of words, phrases, and clauses they produce.

If acquisition involves accumulation of instances of particular words and syntactic structures, and use of this information in the construction of language, more diverse input should lead to greater language growth. This is because, for a passage of speech of fixed length, greater diversity will provide a more complete sample of possible forms of expression. For example, in this account, a child receiving input from a caregiver who uses few structurally complex sentences might be expected to construct a simpler grammar than a child receiving input from a caregiver who uses a larger variety of structurally complex sentences. In a study of the diversity of caregiver speech, Huttenlocher, Vasilyeva, Waterfall, Vevea, and Hedges (2007) found wide variations in diversity across different caregivers.

In addition to using diversity measures of caregiver speech in evaluating the role of input in language growth, we also use diversity measures to assess children's language outcomes. The variety of words and syntactic forms children produce when progressing from single words to structurally complex sentences provides an index of their growing mastery of their language. Diversity of caregiver and child speech has been examined previously in the literature (cf., Naigles and Hoff-Ginsberg, 1998), and is especially familiar in the measure of word types (e.g., Brown 1973). However, previous studies have been limited to diversity of words (number of word types), and of specific syntactic forms (e.g., verb phrases). In the present study, we have devised an overall analytic scheme which we use to examine diversity at lexical, phrasal and clausal levels in both caregivers and children.

## Relation of Caregiver Speech to Child Language Acquisition

In the last thirty years, longitudinal studies have shown that there are individual differences in various aspects of caregiver speech to children, and corresponding differences in the speech of children. Studies have examined caregiver speech at one point in time in relation to child speech at the same or a later time (e.g., Hoff-Ginsberg, 1985; 1986; 1998; Newport, Gleitman and Gleitman, 1977; Pan, Rowe, Spier, and Tamis-Lemonda, 2004). For vocabulary, individual differences have been found in the numbers of word tokens and word types by caregivers, and these are related to differences in children's vocabulary size (e.g., Huttenlocher et al, 1991; Hart and Risley, 1995; Hoff-Ginsberg, 1998; Hoff, 2003a, 2003b).

For syntax, individual differences have been found in the frequency of various structures in caregiver speech, and these differences are related to the development of those structures in children's speech (e.g., Huttenlocher, Vasilyeva, Vevea, Cymerman, and Levine, 2002). Greater frequency of auxiliary-fronted questions in the input is associated with more rapid growth of auxiliaries in child speech (e.g. Furrow, Nelson, and Benedict, 1979; Newport, Gleitman, and Gleitman, 1977). Variations in the frequency and variety of verb frames in caregiver speech predict child verb use (Naigles and Hoff-Ginsberg, 1998). Further, the average number of noun phrases per utterance in caregiver speech varies, and is a predictor of the number of noun phrases in children's utterances (Hoff-Ginsberg, 1986). Such patterns of findings show that amount of exposure to particular syntactic forms is related to the acquisition of corresponding forms in the child, consistent with a constructivist model in which children acquire language from the input.

In summary, existing findings show that variation in the speech of different caregivers is related to the growth of those forms in children. In many studies, the directionality of the relation is ambiguous, because observed correlations could be due in part to common conversational topics in a single session, or possible child influences on the caregiver. The present study provides a comprehensive examination of the relation between caregiver and child speech, using a methodological approach aimed at minimizing the possibility of alternative interpretations.

### Relation of Demographic Factors to Child Language Acquisition

Demographic factors are related to individual differences in the speech of both caregivers and children. Higher SES parents tend to talk more than lower SES parents (e.g., Hoff-Ginsberg, 1990). Further, SES differences are found both for vocabulary (e.g. Hart and Risley, 1992) and for syntax (e.g. Huttenlocher et al., 2002). Lower SES parents use fewer word types and tokens than higher SES parents, and these differences are predictive of child vocabulary (Hoff-Ginsberg 1990; Hoff 2003a, 2003b). Also, lower SES caregivers use fewer multi-clause sentences and smaller numbers of noun phrases per sentence, and corresponding differences are found in the speech of their children (Huttenlocher et al., 2002). Huttenlocher, et al (2007) examined SES differences in caregiver speech in the same sample of families as in the present study. Substantial SES differences were found in the diversity of sentence types caregivers produced. (Children's speech was not examined in that study.)

In addition to SES, child birth-order has been shown to be related to differences in caregiver and child speech. Firstborn children typically receive more speech than later borns (e.g., Hoff-Ginsberg, 1998; Oshima-Takane, and Robbins, 2003; Snow, 1972). Hoff-Ginsberg (1998) also found greater complexity of caregiver speech to firstborns than to later-borns, and showed that this difference was associated with more advanced language in firstborns.

While SES and child birth-order are associated with individual differences in children's syntactic skills, the mechanisms underlying this relation are not yet clear. Previous research on children's vocabulary growth suggests that SES differences might be mediated by variations in caregiver speech (Hoff, 2003b; Rowe, 2008). Here, we address the question of whether the relation of demographic factors to syntactic growth also might be mediated by caregiver speech.

## The Present Study

The present study concerns children's language growth, especially syntactic growth, and explores how variations in caregivers' input affect language outcomes in children. We treat children's speech as an index of their language knowledge, and examine the relation to caregiver speech over an extended time period from 14 to 46 months. Diversity (variety) of speech is used as the language measure for both caregivers and children. To assess diversity of the lexicon, we count the number of word types individuals produce. To assess diversity of syntax, we examine syntactic structures at two hierarchically organized levels – within clauses (constituent diversity) and across clauses (clausal diversity).

At each level, several different devices are identified. The term "device" is used here to encompass words, phrases and clauses, as described under Analysis of Speech below (e.g., within a clause, there are adjectives, prepositional phrases, etc., and, across clauses, there are subject relative clauses, object complement clauses, etc.). While the number of devices at each level is limited, the variety of sentences that can be produced with these devices is *not* limited, since these can be combined or used recursively to produce structurally different sentences.

It should be noted that diversity measures at one syntactic level are independent of those at the other level. That is, it is possible that a person often modifies nouns or verbs but only rarely uses multiple clauses, or vice versa. Individuals may vary in the number of different devices they produce at either or both levels. We apply this coding scheme to both child and caregiver speech, in order to determine which aspects of development differ across children and which aspects of input may influence development.

We construct a growth trajectory for each diversity measure for each child over the entire period of study. Trajectories are described by three parameters: intercept, linear growth, and (when appropriate) quadratic growth. After constructing the growth trajectories, we examine what aspects of caregiver speech predict the parameters of child growth. Further, we examine if demographic factors are related to child growth, determining if birth order and SES predict language growth, and if these factors might be mediated by caregiver speech.

We use lagged correlations, examining caregiver speech and child speech four months apart. That is, caregiver speech at the 22-month observation is used to predict child speech at 26 months, caregiver speech at 26 months to predict child speech at 30 months, and so on. Lagged correlations allow us to explore enduring relations between caregivers and children. In addition to protecting against spurious findings resulting from incidental factors in particular sessions, lagged correlations allow us to explore possible directionality in caregiver/child relations. If caregiver speech at one session is correlated with child speech at a later session, it suggests that caregiver speech may affect child speech.

To further explore the possibility of directionality in the relation between caregiver and child, we also examine if earlier child speech is related to later caregiver speech. If forward correlations are significant, but backward relations are not, we tentatively conclude that caregiver speech influences child speech, either because the child constructs a language system inductively from the input, or, possibly, because input triggers a preexisting system. On the other hand, if forward and backward correlations are equally large, we tentatively conclude that children may affect caregivers as well as vice versa, or that correlations are based on biological similarity between the caregiver and the child (genetic relations would be bi-directional). Finally, we determine if directionality differs for different aspects of language; e.g., whether directionality is greater for syntax than for the lexicon. In sum, this study provides a comprehensive look at the range of structures that caregivers and children produce during language acquisition, and evaluates the relations between them.

## Method

**Participants—**The participants were 47 parent-child dyads from the Chicago area, drawn from a larger, ongoing longitudinal study of 64 families. The families were recruited for the study via a direct mailing to approximately 5,000 families in the Chicago area or via an advertisement in a free, monthly parenting magazine. We asked parents who responded to participate in an over-the-phone questionnaire where we collected information on the child's gender and birth order as well as information on family income, parental educational level, race and ethnic identification. We then selected 64 subjects who matched as closely as possible the 2000 census data on the Chicago area. This resulted in an economically, ethnically, and educationally diverse sample.

Our subset of 47 families met the following criteria: 1) the native language of the parent was English and English was the dominant language in the home, and 2) the same parent was filmed at a majority of the visits. This resulted in a sample of 47 families; in 45 families, the mother was the primary caregiver, and in two families, the father was the primary caregiver (26 boys and 21 girls). Division of the sample into four educational levels, six income levels, and four racial groups is shown in Table 1. The numbers of families where the target child was first born or later born also is shown in Table 1.

**Procedure—**Families were visited in their homes every four months for a total of nine visits. The experimenter videotaped the speech of caregiver and child for 90 minutes during their ordinary daily activities, interacting only minimally. Occasionally, a visit was missed due to an illness in the family. However, no family missed more than two visits, and no more than two families missed any single visit. While we obtained speech samples starting at 14 months, children's speech was sparse through 22 months. In order to analyze all aspects of children's speech over the same time period, we began our statistical analyses at the 26 month visit, but we provide child speech data starting at 14 months in the tables in the Results.

**Transcription of speech:** Transcripts were made from collected videotapes. All caregiver and child speech was transcribed with the exception of nonsense babbling (e.g., *ga ga ga ga*). For caregiver speech, only speech to the target child was transcribed. The flow of speech for both children and caregivers was divided into utterances. We defined an utterance as having a single intonational contour within a single conversational turn and consisting of one or more syntactic units (e.g., constituents or clauses). An intonational contour typically involved either rising pitch (associated with questions) or falling pitch (declaratives and commands). An utterance was usually preceded and followed by a pause, although word-searching pauses were ignored when dividing speech into utterances. In short, under our definition an utterance could contain a single word (*cookies*), a single phrase (*in the box*), a simple sentence (*Mikey fell down*), or a multi-clause sentence (*I don't want you to put it there*). Two independent clauses, occurring within the same conversational turn, were considered separate utterances unless they were connected by intonation or a lexical item (e.g. *and*, *because*).

**Reliability of transcription and of syntactic analysis:** Two different reliability measures were applied. The first concerned the reliability of the transcription. For a random 20% of transcripts, a second person transcribed 10% of the utterances. Reliability was at or above 95%; conflicts were resolved by a third judge. The second measure concerned the reliability of syntactic coding. For a random 33% of transcripts, a second person coded 10% of utterances. Again reliability was at least 95%, and conflicts were resolved by a third judge.

## Analysis of speech

**Diversity Measures of Caregivers' and Children's Speech—**At the heart of the present paper is the analysis of the diversity of caregiver and child speech, and examination of the relation between these. Our analysis examines lexical diversity (word types), and syntactic diversity, a refinement of the diversity analysis described by Huttenlocher et al (2007). It distinguishes two levels of syntactic diversity: (1) modifications within a clause (at a constituent level) or (2) additional clauses (at a clausal level). Several syntactic devices are identified at each level. By analyzing syntax at two levels, we capture hierarchical organization in sentences via the nesting of constituent structures within clausal structures (e.g., the adjectival modification of the subject of a subordinate clause). In addition, devices at either level can be applied recursively to structures that are themselves augmented (e.g. *a bite of a slice of cheese; I know you think it's icky*).

**Measuring Lexical Diversity (i.e., Word Types):** Lexical diversity is the number of different words (word types) produced at a session. For example, if a given transcript has the word "ball" used 10 times, that transcript would have one word type. For our analysis, we treated all inflected forms of a word as the same type (e.g. *eat*/*eats*/*eating* = 1 type; *girl*/*girls* = 1 type). Words with irregular inflectional morphology were also counted as one type (e.g. *sing*/*sang* = 1 type, *foot*/*feet* = 1 type). Words with different derivational morphology, however, were treated as different types (*quick*/*quickly* = 2 types). Variations on proper names and nicknames were counted as one type (*Joshua*, *Josh* = 1 type). Proper names, book titles, etc., containing more than one word were treated as a single type (*StrawberryShortcake* = 1 type; *TheLittleRedHen* = 1 type).

For children, lexical diversity is a measure of vocabulary size, and is typically assessed in either of two ways. One way is to calculate the number of different words produced by an individual at a particular session. The other is to calculate cumulative vocabulary – the total number of different words a child has produced up to a particular time point. Only the first of these measures can be used for adults since it is difficult to calculate all the words a caregiver knows; although, while the number of words used in a session will include only a small proportion of the words an adult knows, that number can be used as an index of the caregiver's vocabulary. In order to use the same measures for adults and children in various statistical analyses, we chose a non-cumulative vocabulary measure for children, namely, the number of different words produced during a particular session.

**Measuring Constituent Diversity:** Constituent diversity is a measure of different optional elements (words or phrases) used within a clause. We have identified seven different forms (types) of constituent augmentation, as indicated in Table 3. Three of these modify nouns or verbs: (1) *adjectives* (e.g. *pink bunny*, *big boy*), (2) *adverbs* that modify verbs (e.g. *run quickly*, *jump far*), and (3) adverbs that modify adjectives or adverbs (e.g. *really soon*, *very pretty*). Four are phrases: (4) prepositional phrases (e.g. *In the morning, we're going to Grandma's*); (5) noun phrases occurring with no preposition and outside of argument positions (e.g. *Last night we went to the store*.); (6) possessives (e.g. *your daddy's shoes*; *the kitty's food*); and (7) quantifiers (units) for mass nouns (e.g. *a glass of water*, *a bite of cheese*).

Our constituent diversity measure specifies the number of types of modifications produced by an individual during a particular session. Although structures can be embedded in one another, such embeddings only happen in children's speech after 46 months. Because we are concerned with the predictors of child speech, we analyze only structures which are produced both by caregivers and by children by 46 months of age; the number of structures used by both children and caregivers ranged between 0 and 7.

**Measuring Clausal Diversity:** Clausal diversity is a measure of different ways of combining clauses. For two clause sentences, we have identified seven different types of structural relations. We list the types of structural relations below, and provide the abbreviation used for each in Table 4 here. (1) The first type is coordination – two clauses conjoined by *and* or *or* (e.g. *I went home and slept*) (CO). The second and third types are adjunct clauses that, either (2) precede the main clause (i.e., adjunct clause first) (e.g. *Before you go outside*, *put on a sweater*) (A1), or (3) follow the main clause (i.e., adjunct clause second) (e.g., *Put on a* *sweater*, before you go outside) (A2). The fourth and fifth types are relative clauses that either (4) modify the subject of the main clause (i.e., subject relative clause) (e.g. *the one I want is over there; the girl that knows Grandma is coming over today*) (SRC), or (5) modify the object of the main clause (i.e., object relative clause) (e.g. *I know the one you want; I saw the man who works with Daddy at the store*) (ORC). The sixth and seventh types are subordinate clauses that are either (6) the subject of the main clause (i.e., subject clause) (e.g. *Sitting still is not fun*) (SC), or (7) the object of the main clause (i.e., object clause) (e.g., *I think it's over there*) (OC). We do not treat serial verb constructions (e.g., *go get it*), modals (e.g. *going to do it*), or tags (e.g. *isn't it*?) as constituting multi-clause utterances.

The clausal diversity measure specifies the number of types of clausal combinations used by an individual in a particular session. It should be noted that, in caregiver speech, and even in child speech, one of the seven basic types of clausal combinations was occasionally combined with another, thus forming a new type of multi-clause sentence with three clauses. While there is no fixed limit for clausal diversity, numbers of structures for children typically ranged between 0 and 7, whereas for caregivers, numbers ranged as high as 30.

In summary, we describe the diversity of speech by caregivers and children at three levels (at a lexical level, and at constituent and clausal syntactic levels). We are concerned with whether child outcomes at one level are predicted chiefly by diversity at the corresponding level in caregiver speech, or whether child outcomes can be better predicted by also using data from non-corresponding levels of caregiver speech. For example, we examine whether children's use of constituent devices is predicted better when caregivers' clausal diversity or lexical diversity also are included in the analysis. If acquisition involves induction of grammatical principles from the input, corresponding forms should be strengthened by exposure; non-corresponding forms may be strengthened less, or not at all.

**Quantity Measures of Caregiver speech—**Quantity of caregiver speech is examined in two ways. First, we tally the *frequency* of particular types of elements, either number of word types or number of types of syntactic structures, e.g., noun phrases, subject relative clauses. The number of elements of particular types across caregivers is compared to age of acquisition of those types across children. Second, we measure the total amount of speech as the number of word tokens produced by a caregiver at a session – henceforth referred to as *quantity*. Quantity is included along with caregiver diversity as a predictor of child diversity for each outcome measure. Diversity and quantity of caregiver speech were initially analyzed separately as predictors, and then were considered simultaneously. The relative importance of diversity versus quantity as predictors is explored for each child outcome measure by determining if one remains significant when the other does not, or if one is more significant than the other.

## Results

In examining the growth of children's language, we are concerned with three issues. The first is how children's speech changes over time and whether there are significant individual differences among children. We analyze children's growth trajectories for each of our three diversity measures (i.e., lexical diversity, constituent diversity, and clausal diversity). For each, we determine the form of growth over time (linear or curvilinear). Then we assess whether there are significant individual differences for any of the parameters of growth -- intercept, linear growth, and, where appropriate, quadratic growth.

After characterizing individual differences in language growth, we turn to the two issues that are the main concern of this paper. The first issue is whether language outcomes assessed for individual children can be predicted by the diversity or quantity of speech of their caregivers. We evaluate possible directionality by determining whether child speech can be predicted by caregiver speech, and also whether caregiver speech can be predicted by the speech of children.

The second issue is whether child outcomes can be predicted by demographic factors, i.e. birth order status, gender, or SES, and whether these factors might be mediated by the speech of individual caregivers.

## Children's growth

Table 2a shows the average number of utterances produced by children at each age, as well as average diversity at lexical, constituent, and clausal levels produced by children. The average number of different lexical items increased from 7.86 at 14 months to 283.49 at 46 months. The distribution was highly skewed when children were very young. At 14 months, most children used only a small number of words (60% used under 5 words; 80% used under 10 words), although a few children already used a larger number of words. At both constituent and clausal levels, diversity increased from essentially zero at 14 months, to over 5 by 46 months. However, the trajectory of growth differed at the two levels; clausal diversity emerged later than constituent diversity, and increased more rapidly. Children started to use constituent forms by 18 months, whereas clausal level forms first appeared at 26 months. Tables 3a and 4a show the average number of uses of different devices by children at a particular level (constituent or clausal) at each age. Particular constituent devices (e.g., adjectives) were used more frequently than particular clausal devices (e.g., object relative clauses) and emerged earlier.

For each of the three diversity measures of child speech, we employed hierarchical linear modeling (HLM; Raudenbush, Bryk, Cheong, and Congdon, 2000) to describe and analyze the shape of children's growth trajectories. HLM provides a way to handle dependencies caused by nested data structures, as in our data. It is particularly useful for growth curve analysis, where observations measured at various times are nested within an individual. One advantage of HLM over other methods for growth curve analysis is the capacity to handle situations like ours, where measures for particular individuals are missing at some time points. Since there were only sufficient data to analyze all measures statistically starting at 26 months, the HLM analyses cover the period from 26 through 46 months.

For each child, a linear regression model was fit for each diversity measure with the age of the child as the sole predictor. This was compared to a model with a quadratic term, which allowed squared age to predict curvature in the change trajectory. After determining which model best describes the growth, we summarize across children by considering the mean and variation of growth parameters. Tests of the linear and quadratic components of the growth trajectories are shown in Table 5. For lexical diversity and for constituent diversity, both the linear and quadratic components were highly significant. The quadratic growth components were negative, indicating that the rate of growth diminishes with child age. For these measures, we continue our analyses using a quadratic growth model. For clausal diversity, in contrast, the quadratic growth component is non-significant, so our analysis uses a linear growth model.

The average growth trajectory for the child measures of diversity at each of the three levels is shown in Figures 1, 2, and 3, with the observed means at each age superimposed on the plots. All measures increased from 26 to 46 months. The figures illustrate that growth gradually decreased over time for lexical diversity and for constituent diversity. There was still some positive growth at 46 months for lexical diversity, but, for constituent diversity, growth leveled off by 46 months. Nevertheless, there is evidence that growth is not complete by 46 months; embedded devices at the constituent level only emerge after four years of age and hence are not included in the analysis. For clausal diversity, there is no evidence of slowing of growth over the age range of the study; growth increased linearly across the total age range. However, a quadratic component would be expected at a later age, since the diversity of multi-clause sentences is likely to level off as child speech comes to approximate adult speech. Such a reduced growth rate does not occur by 46 months, and hence is not included in our growth model.

**Individual Differences Among Children—**Our HLM analyses show substantial individual differences among children. The HLM analysis estimates a variance of growth that represents individual differences in how language develops over time. Square roots of those variances (i.e. standard deviations) are shown in Table 6, along with tests of whether they differ significantly from zero. For lexical and constituent diversity, there are significant individual differences in all aspects of growth: intercept (i.e. the starting points at the age of 26 months), linear slope (i.e. the amount of growth expected for each four-month increase in age) and quadratic change (i.e. change over time in the rate of growth). For clausal diversity, no significant variation is found in intercepts across children, seemingly because at 26 months children show almost no clausal diversity. However, there are significant individual differences in linear change. That is, we find no individual differences in clausal diversity at 26 months, but children grow at different rates as they become older.

**Stability of Individual Differences Among Children—**To address questions of the stability of individual differences, we investigate whether children tend to maintain the same position relative to other children as time passes. We employ Kendall's coefficient of concordance (*W*), a non-parametric statistic that assesses the similarity in rank ordering of a variable over several measurement occasions. Table 7 presents the estimated value of Kendall's *W* for each measure. Values of *W* near zero indicate lack of consistency in rank ordering; values near one indicate near perfect consistency. *W* is significantly different from zero for all three measures. Consistency in ranking over time is remarkably high for lexical diversity and clausal diversity, and is fairly high for constituent diversity. Thus, children who are at a particular level on a measure at a particular time remain in a roughly comparable position relative to other children over time. In summary, our examination of diversity in children's language over time suggests that diversity provides measures of growth at lexical, constituent, and clausal levels.

### Predictors of children's language growth

We examine two classes of potential predictors of child speech; those that may change in real time as the child ages (caregiver speech) and those that are stable across time (demographic variables). In HLM, variables of the first type (so-called "time-varying covariates") are entered into the individual growth equations along with child age. In contrast, variables that are stable across time are used to predict the components of the individual growth curves (intercept, linear growth, quadratic growth). Because of these very different ways in which the two classes of variables are used, we follow a consistent sequence of analysis. First we consider caregiver input to assess if input predicts child speech. Next, we determine, for each level of child speech, if growth is predicted chiefly by corresponding structures in caregiver speech. Finally, we consider demographic predictors to assess if the shape of individual growth curves varies as a function of these predictors, and to explore whether the effects of demographic factors may be mediated by caregiver input (cf. Baron and Kenny, 1986).

**Age of acquisition in relation to frequency of caregivers' use of specific structures—**Table 2b shows the average number of utterances produced, and average diversity at lexical, constituent, and clausal levels, for caregivers at each child age. Within a given level, variation in the number of uses (i.e., frequency) of different devices by caregivers at each child age is shown in Tables 3b and 4b. Children's acquisition of more frequent devices was earlier than for less frequent devices. (See Tables 3a and 4a.) For example, at the constituent level, adverbials were used more frequently across age by caregivers than possessives: adverbials were produced starting at 14 months, whereas possessives were first produced at 22 months. At the clausal level, object complements were produced most frequently by caregivers, and children produced them starting at 22 months, the next most frequent were adjunct clauses in second position, and children produced them starting at 26 months.

Clearly there is a relation between the frequency of particular devices across caregivers, and the emergence of those devices in children. While the trend described is visually apparent in the tables, statistical confirmation is somewhat elusive, as age of onset is difficult to define. We address this issue by treating age of onset as the first age at which the mean for the measure is significantly different from zero. Rank regressions of these ages on caregiver frequency for the same measure were highly significant ($t_5$ = 9.40, $p$ < .001 for Table 3 and $t_5$ = 5.17, $p$ < .01 for Table 4).

**Language growth in relation to diversity and quantity of caregiver speech—** Given the considerable variability in caregiver speech and in child language growth (as seen in Tables 3b and 4b), we next examined if the speech of particular caregivers was associated with language growth in individual children. We examined both diversity and quantity of caregiver speech. Caregiver diversity was evaluated as a predictor of child syntactic growth in our lagged analyses for two sorts of situations. One involved corresponding measures, e.g. where caregiver constituent diversity is used to predict child constituent diversity. Note that correspondence here is defined abstractly, i.e., correspondence can be at lexical, constituent, or clausal levels. The other involved non-corresponding measures (where caregiver speech at one level was used to predict child outcomes at a different level); we examined if these are less significant predictors, or not significant at all. Such a finding would support a constructivist account in which corresponding forms are strengthened by exposure.

**Correspondence and quantity for Lexical Diversity:** Children's lexical diversity is predicted by caregiver lexical diversity ($t_{263}$ = 2.75, $p$ = .007). It is also predicted by caregiver quantity ($t_{263}$ = 2.92, $p$ = .004). When the two predictors are considered simultaneously, both become highly non-significant ($t_{262}$ = 0.95, $p$ = .346 for caregiver frequency, and $t_{262}$ = 0.61, $p$ = .545 for caregiver lexical diversity). The finding of a high degree of overlap between these two predictors of children's lexical diversity is consistent with the earlier literature and with our findings, presented in Table 8, showing that number of word types (lexical diversity) is highly correlated with number of word tokens (quantity). Hence, either measure might be used to predict vocabulary growth.

**Correspondence and quantity for constituent diversity:** Children's constituent diversity is predicted by caregiver constituent diversity, or by overall quantity of caregiver speech, reflecting overlap between these predictors. However, caregivers' constituent diversity is a stronger predictor ($t_{263}$ = 3.09, $p$ = .003) than caregiver's quantity of speech ($t_{263}$ = 2.36, $p$ = .019). When both caregiver measures are considered simultaneously, caregiver constituent diversity remains significant ($t_{262}$ = 2.29, $p$ = .023), while quantity does not ($t_{262}$ = 1.13, $p$ = .262). Thus, caregiver constituent diversity is the better predictor of child constituent diversity.

**Correspondence and quantity for clausal diversity:** Children's clausal diversity is predicted either by caregiver clausal diversity or by number of caregiver uses. When considered separately, both are significant predictors of children's clausal diversity ($t_{263}$ = 2.98, $p$ = .004 and $t_{264}$ = 3.18, $p$ = .002, respectively). When both are considered simultaneously, caregiver clausal diversity is non-significant ($t_{263}$ = 1.26, $p$ = .208) and quantity of speech is only marginal ($t_{263}$ = 1.68, $p$ = .093). Either measure can predict the clausal diversity of children's speech because of the correlation of quantity of speech with clausal diversity.

In summary, diversity of caregiver speech predicts child growth at corresponding levels. Overall quantity of caregiver speech also predicts child growth. The diversity measures allow us to further explore the role of caregiver input by examining if non-corresponding diversity is as good a predictor as corresponding diversity. If a non-corresponding measure is a significant predictor, we consider that measure simultaneously with the corresponding measure to see if one dominates.[3] If the corresponding measure is a stronger predictor, it would suggest that exposure to forms at a particular level strengthens forms at that level, thus supporting a constructivist view of acquisition.

**Non-correspondence and lexical diversity:** Let us consider if children's lexical diversity is predicted by caregivers' syntactic diversity at either the constituent or clausal level (non-corresponding levels). Caregivers' clausal diversity was not a significant predictor of children's lexical diversity ($t_{263}$ = -0.29, $p$ = .772). Caregivers' constituent diversity *was* a significant predictor of children's lexical diversity ($t_{263}$ = 2.06, $p$ = .040), but did not achieve the same level of significance as caregivers' lexical diversity. Nor did it remain significant when caregivers' lexical diversity was included in the analysis. When both constituent and lexical diversity were used simultaneously as predictors, only lexical diversity remained significant ($t_{262}$ = 2.14, $p$ = .033); constituent diversity became non-significant ($t_{262}$ = 1.11, $p$ = .268). Thus, it is the diversity of caregivers' lexical input, not of their syntactic diversity at either level, that best predicts children's lexical diversity.

**Non-correspondence and constituent diversity:** Consider now if children's constituent diversity is predicted by caregivers' lexical or clausal diversity. Caregivers' clausal diversity did not significantly predict children's constituent diversity ($t_{263}$ = 0.80, $p$ = .424). While children's constituent diversity was predicted by caregivers' lexical diversity ($t_{263}$ = 2.77, $p$ = .007), when both lexical and constituent diversity of caregiver speech were included, lexical diversity became non-significant ($t_{262}$ = 1.29, $p$ = .199), whereas constituent diversity is marginal ($t_{262}$ = 1.93, $p$ = .055). Thus, it is the diversity of constituent input, not of lexical or clausal input, that best predicts children's constituent diversity.

**Non-correspondence and clausal diversity:** Finally, consider if children's clausal diversity is predicted by caregivers' lexical or constituent diversity. Here, the results are markedly different; either lexical or constituent diversity in caregiver speech predicted children's clausal diversity, ($t_{264}$ = 3.65, $p$ = .001 for lexical diversity, $t_{264}$ = 3.36, and $p$ = .001 for constituent diversity). Moreover, each predictor remained significant when included simultaneously with caregivers' clausal diversity, but, in that case, clausal diversity became non-significant. With caregivers' clausal and lexical diversity included, $t_{263}$ = 2.22, $p$ = .027 for lexical diversity, and $t_{263}$ = 0.88, $p$ = .378 for clausal diversity. With caregivers' clausal and constituent diversity included, $t_{263}$ = 2.43, $p$ = .016 for constituent diversity, and $t_{263}$ = 1.86, $p$ = .064 for clausal diversity. Thus, diversity of caregiver speech at non-corresponding levels predicted children's clausal diversity, and, curiously, the effect was stronger than for corresponding measures.

In summary, at lexical and constituent levels, it is corresponding levels of caregiver diversity which predict child growth. That is, syntactic diversity of caregiver speech does not much affect the child's lexical growth, nor does the lexical diversity of caregiver speech much affect constituent level syntactic growth. In contrast, all aspects of diversity (at lexical and constituent levels as well as at the clausal level) seem to strengthen the clausal diversity of the child's speech, a matter we address in the Discussion.

**Reverse-lagged analyses—**Recall that, for all three diversity measures, caregiver speech is significantly correlated with child speech four months later. To evaluate possible

[3]We do not simultaneously investigate all three measures since the potential for near-collinearity would make estimation unstable. The condition number, a diagnostic for collinearity that describes the linear redundancy of predictors, ranges in our data from 121.2 to 252.0 across the six time points. Since values greater than 30 indicate possible problems, our results strongly suggest that collinearity is a concern here.

directionality of the relation, we also present analyses where the direction of the prediction and the lag are reversed. If reversed analyses are non-significant, it would suggest that caregiver speech affects the child, not vice versa. On the other hand, if earlier children's speech also predicts later caregiver speech, it would suggest that caregiver speech not only *leads to*, but also *responds* to child speech, reflecting mutual causation, or, possibly, biological similarity between parent and child.

It should be noted that, if significant effects are found in both directions, the interpretation of reverse-lagged analyses is ambiguous. A significant reverse-lagged analysis could result if forward caregiver effects lasted across several visits. Although several interpretations are possible when both forward and reverse-lagged analyses are significant, this is not the case for unidirectional relations. That is, if caregiver speech predicts later child speech and is *not* predicted by earlier child speech, the results strongly suggest that caregiver input is causally related to child growth.

For each of the three measures, we duplicated the model building process, only this time predicting later caregiver speech with children's earlier speech and demographic factors as predictors. For lexical diversity, the final model that resulted from reverse-lagged analysis showed that caregivers' later lexical diversity was a significant predictor ($t_{45}$= 3.05, $p$ = .004). This result suggests a bi-directional relation for lexical diversity.

While reverse correlations are clearly significant at the lexical level, this was not true at either syntactic level. Children's clausal diversity was not a significant predictor of clausal diversity of caregivers' speech ($t_{262} = -1.32$, $p$ = .190). Nor was children's constituent diversity a significant predictor of constituent diversity in caregivers ($t_{262}$= 1.871, $p$ = .062). However, even though results for both levels of syntactic diversity differed from those for lexical diversity, the two levels of syntactic diversity (constituent and clausal) differed from each other. Evidence of uni-directionality was most striking at the clausal level, showing the strongest evidence that caregiver speech is a source of child growth for clausal level structures. In the Discussion, we consider why the relation of input to child growth might differ at lexical and syntactic levels, and why the relation for syntax might be more asymmetric at a clausal than a constituent level.

**Demographic Factors as Predictors—**Finally we consider demographic factors as predictors, including gender, firstborn status, and SES. For each child outcome, we examined demographic variables as predictors of the simplest aspects of growth that vary significantly across children. For lexical and constituent diversity, that was the intercept of the growth curve. For clausal diversity, however, the intercept did not vary significantly (cf. Table 6), so we considered demographic factors as predictors of linear growth. Child gender was supremely ineffective as a predictor; in the age range we examined statistically, from 26 to 46 months, it never approached even marginal significance. Further, firstborn status was not a significant predictor of either lexical diversity or constituent diversity, although it did predict clausal diversity (i.e. the linear slope) ($t_{45}$ = 2.712, $p$ = .035), increasing the growth rate by almost 50% for firstborn children compared to other children.

SES, in contrast to gender and firstborn status, was a highly significant predictor of child language at all levels, with either education or family income as SES measures. For education, we used a quasi-continuous variable where high school education was treated as 12 years of education, some college as 14 years, college graduation as 16 years, and post-graduate education as 18 years. For income, we used a quasi-continuous variable involving the midpoints of the reported income ranges.[4]

Graphical examination of the relation of child language to either SES measure is appropriate for examining individual differences in language growth. The Pearson correlation between education and income is $r = .42$ ($df = 48$, $p = .003$) in our sample. Thus when one of these variables can predict an aspect of growth, the other often can as well. When both predictors were used simultaneously, one generally emerged as significant when the other was controlled. Although income and education can sometimes predict more than one aspect of growth (e.g. intercept and linear slope), two predictors never are *simultaneously* significant predictors of more than one aspect of growth. Hence, we present the model where the simpler aspect of growth is predicted (i.e., the intercept, or, for clausal diversity, linear growth). Log (income) consistently emerged as a stronger predictor than caregiver education, so we used income as our SES measure. Table 9 summarizes the findings.

SES (income level) predicts the intercept for both lexical diversity and constituent diversity. Figures 4 through 6 show modeled growth curves as a function of SES. In these figures, the lowest curve is for families with incomes of $12,500, and the highest curve is for incomes of $112,500. The intervening curves are the model-predicted values for incomes of $25,000, $42,500, $62,500, and $87,500. Here, there are significant SES differences in intercept. In contrast, for clausal diversity there is no significant variation in the intercept, but SES predicts the slope of the growth curve. As shown in Figure 6, the curves for clausal diversity begin at the same point at 26 months, but grow at different rates depending on SES (income level). Thus while SES effects remain constant over age at lexical and constituent levels, they increase at the clausal level. It is not clear whether this increase will continue to grow at later ages.

For clausal diversity, in addition to SES, firstborn status also is associated with accelerated growth. That is, when both variables were included in the analysis as predictors of linear growth, both were highly significant for SES ($t_{44} = 2.835$, $p = .007$) and for firstborn status ($t_{44} = 2.787$, $p = .007$). It should be noted that firstborn status is mildly confounded with gender in this data set (*phi* coefficient = .17), but that the association is non-significant ($X^2 = 1.40$ with 1 $df$, $n = 47$, $p = .237$). Given the non-significance of gender, it seems unlikely that this association explains the firstborn effect. More likely, it is the association of firstborn status with caregiver speech that is important.

**Are demographic effects mediated by caregiver speech?—**Finally, let us consider if demographic effects on language growth might be mediated by differences in the speech of caregivers from different groups. To evaluate whether SES effects might be mediated by caregiver speech, we considered predictive models that incorporated both language input and SES. Beginning with either a linear or quadratic model, depending on the variable, we included the corresponding caregiver speech measure and added the demographic factors that were significant when caregiver speech was not considered. If the demographic variables were no longer significant when caregiver input was included, we tentatively concluded that the effect was entirely mediated. If demographic variables remained significant when caregiver speech was added, we considered whether the effect was attenuated, suggesting that demographic effects were partially mediated by caregiver speech.

Since the results suggested mediation, we used a Sobel test to determine whether the mediation was significant. (See Krull and MacKinnon, 1999, for a discussion of mediation with multi-level models.) Although use of the Sobel test may be questionable when sample size is relatively small (see, e.g., Preacher and Hayes, 2004; Preacher and Hayes, 2008), the alternative

[4]This method for handling education and income was chosen primarily to maximize power. However, it also has the advantage of requiring that any changes associated with these predictive variables be monotonic; treating such predictors as categorical can allow anomalies where, for example, a lower education group with a small sample size is estimated to have higher scores than a higher education group, even though the overall trend involves a positive association.

of using resampling methods is impractical with HLM. Further, it should be noted that criticisms of the Sobel procedure with small samples are primarily related to lack of power than to invalidity. Hence, a marginal Sobel result would be of interest and a significant Sobel test would strongly suggest mediation.

**Mediation for lexical diversity:** We had found that SES predicts the intercept of the growth curve for lexical diversity. When caregivers' lexical diversity was included as a predictor, both SES ($t_{45} = 3.32$, $p = .002$) and lexical diversity ($t_{262} = 2.31$, $p = .022$) were significant. However, the significance of SES was reduced (i.e., in the analysis in which SES was considered in the absence of caregiver input, $t_{45} = 3.77$, $p < .001$; see Table 9). This pattern of results at least weakly suggests mediation. When a Sobel test was used to evaluate whether caregivers' input (lexical diversity) mediates the effect of SES, the result was marginal ($Z = 1.86$, $p = .063$).

**Mediation for constituent diversity:** SES also predicts the intercept of the growth curve for constituent diversity. Here, with caregivers' constituent diversity also in the model, SES becomes non-significant ($t_{45} = 1.27$, $p = .210$), while the caregiver measure remains significant ($t_{262} = 3.44$, $p = .001$). A Sobel test ($Z = 2.09$, $p = .037$) is significant. This pattern suggests that caregivers' constituent diversity completely mediates the effect of SES on children's constituent diversity growth.

**Mediation for clausal diversity:** For clausal diversity, there was no significant variation in the intercept of the growth curve, so we modeled variation in the linear slope. Both SES and first-born status predicted growth rate. This effect persisted when caregivers' clausal diversity was included as a predictor: all three variables were significant ($t_{44} = 2.45$, $p = .018$ for SES, $t_{44} = 2.66$, $p = .011$ for first-born status, and $t_{262} = 2.66$, $p = .009$ for caregiver input). The magnitude of the effects for SES and first-born status were substantially smaller when caregiver input was included, suggesting that demographic factors may partially mediate caregivers' clausal diversity. However, a formal test was not possible because the demographic variables predict the *slope* of the growth curve rather than the intercept, and are thus not directly comparable to variables that predict clausal diversity directly.

In summary, SES effects at all language levels seem to be mediated by caregiver speech. Findings at lexical and constituent levels are highly suggestive, although not definitive. At the clausal level, while the pattern also suggests mediation, a formal test is not possible. We tentatively suggest that, at least in part, the SES relation to language growth reflects variations in caregiver speech. The proper interpretation of SES effects seems to be that they reflect the fact that caregiver speech affects child language growth.

## Discussion

The present study examined the longitudinal relation between language input and child language acquisition. The study incorporated several key methodological features which allowed us to obtain data supporting a constructivist interpretation of the association between caregivers' speech and children's language growth. These include (1) use of diversity measures of speech, (2) examination of directionality in lagged regression analyses, and (3) analysis of caregiver speech as a mediator of the relation between demographic factors and children's language skills. The study clarifies the role of caregiver input in language growth over the period when children progress from single word speech to multi-clause sentences.

### Use of diversity measures of language

We used diversity measures to assess children's language mastery, and to evaluate the variety of structures of caregiver speech. We introduced a scheme for analyzing the diversity of speech

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at different levels – lexical diversity, as well as syntactic diversity, both within clauses (constituent level) and across clauses (clausal level). Our analysis captured the hierarchical organization of language, where constituent level devices are embedded in structures at the clausal level. Using this limited set of devices, one can produce an infinite variety of sentences, a hallmark of the mastery of a language.

We reasoned that more diverse caregiver speech provides more complete samples of the possible patternings of elements in a language (for a fixed length passage). Hence, if syntax is acquired inductively, more diverse caregiver speech should lead to greater language growth. Further, diversity of caregiver speech can be examined independently at different levels; for example, a person may use a diverse vocabulary, but not many types of multi-clause sentences, or vice versa. If syntax is acquired inductively, diversity of caregiver speech at one level might contribute more to child language growth at that level than at a different level.

Indeed, our results showed that more diverse caregiver speech predicted child outcomes for lexical and constituent diversity. While corresponding predictors were related to growth, non-corresponding predictors were not, suggesting that input effects may be specific to a particular level. However, clausal diversity in children was predicted by all aspects of diversity in caregiver speech, apparently fed by input of lexical items and constituent level devices, as well as by input of multi-clause sentences. Below, we discuss possible explanations for this observed pattern of relations between caregiver and child diversity measures.

When considering effects at corresponding levels, it is important to keep in mind that, in the present study, correspondences are very broadly defined. That is, each level of syntactic diversity (constituent and clausal) encompasses a variety of specific structures; e.g., a constituent level of analysis includes adjectival modification, adverbial modification, prepositional phrases, etc. Our findings indicate that the variety of structures used by caregivers at a constituent level predicts the variety of structures at this level used by children. A possible reason is that devices at a phrasal level in caregivers' speech are positioned differently in utterances than devices at a clausal level, e.g., with greater contiguity or adjacency of elements.

It has been established that infants under one year of age can use the transitional probabilities of adjacent syllables to locate word boundaries (e.g., Aslin, Saffran, and Newport, 1999; Gomez and Gerkin, 1999; Saffran and Wilson, 2003). Toddlers have been shown to use words on either side of a target word (i.e., syntactic frames) to correctly assign word class (e.g., Landau and Stecker, 1990; Naigles and Hoff-Ginsberg, 1998). Evidence also suggests that children may first acquire frames for particular words and then later extend that information to classes of words (e.g., Braine, 1976; Brooks, Tomasello, Dodson, and Lewis, 1999; Lieven, Pine and Baldwin, 1997; Pine and Lieven, 1993; Rowland and Pine, 2000; Tomasello, 2000). On this account, our results for corresponding vs. non-corresponding measures are not terribly surprising. We propose that the acquisition of a particular device (e.g., use of adjectives) is more influenced by the use of other adjacent devices (e.g., use of adverbs), and less influenced by unrelated devices with different, non-adjacent structural relations (e.g., adjunct clauses).

This leaves open the question of why children's clausal diversity is also influenced by caregivers' lexical and constituent diversities. We tentatively suggest that this relation may reflect the hierarchical nature of language. That is, once children's knowledge of language includes both lexical items and various types of adjacent structural relations in constituent structures, children can construct larger, non-adjacent relations such as relative clauses or adjunct clauses. Thus children may not be able to produce complex syntax without having knowledge of how words fit into phrases, and how phrases fit into clauses. This hypothesis will require further research.

In addition to looking at the diversity of caregiver speech as a predictor of children's language growth, we also examined quantity of caregiver speech as a predictor. Previous studies have focused on the quantity of speech as a key measure of language input (e.g., Hart and Risley, 1995; Huttenlocher et al., 1991). We measured diversity of caregiver speech as a predictor of individual differences among children and found that, for corresponding forms, diversity is a powerful predictor. However, frequency of specific syntactic structures by caregivers was a strong predictor of the order of acquisition of those structures in children's speech. Structures that were more frequent in caregiver speech emerged earlier in children's speech than those that were less frequent. Some devices at one level were more frequent than others (e.g., at the constituent level, adverbial and adjectival modification were most frequent), and these emerged earlier than the less frequent prepositional phrases. Thus, there was a strong relation between frequency of particular devices and age of emergence in the child.

Under both constructivist and nativist accounts, language is acquired via exposure to the input, and thus children's mastery of a particular word or structure should be related to caregiver use of the forms, e.g., if a child produces relative clauses, we would expect the caregiver to have produced relative clauses in his or her presence. However, a constructivist account also suggests that particular forms will be strengthened via increases in exposure. In other words, in this approach, frequency of specific forms in caregiver speech should be tied to emergence of child production; more frequent forms in caregiver speech should be acquired earlier and produced more frequently. Thus, our pattern of results is consistent with a constructivist account whereby children first acquire words and structures they are most frequently exposed to (e.g., Naigles and Hoff-Ginsberg, 1998).

## Directionality in language acquisition

We used lagged correlations as a method for determining the nature of the relation between caregiver input and child speech, comparing caregiver and child at different time points. Use of lagged correlations prevented inflation of correlations due to temporary factors in particular sessions. Further, it allowed us to explore the possibility of directionality in the caregiver/child relation. From a constructivist perspective, earlier caregiver speech should predict later language growth, whereas there is no such prediction of a relation between earlier child speech and later caregiver speech.

For vocabulary, we found a clear bidirectional relation: earlier caregiver speech predicted later language growth, and earlier child speech predicted later caregiver speech. This suggests a mutual process where children acquire words from caregivers, and where caregivers are influenced by children's vocabularies. Possibly, the words children produce at particular time points provide clues to caregivers as to what kinds of words the child knows, thus affecting their later word use.

For syntax at both levels, in contrast to vocabulary, only forward correlations were statistically significant, supporting a constructivist view of syntactic development. However, the extent of asymmetry differed at the two levels. That is, directionality was less pronounced at the constituent than at the clausal level. We tentatively suggest that this result could be partly explained if caregivers are differentially attuned to children's ability to produce or understand syntactic structures at these two levels. For example, the most frequent constituent structures are very simple, often involving a string of two words (e.g., *big boy*, *go fast*). Children's production and comprehension of this kind of speech may be somewhat apparent to caregivers. For multi-clause sentences, however, caregivers may even be relatively unaware of the structures that they themselves use, and hence may not be sensitive to the structures their children produce and comprehend. Thus, while there is unidirectionality in the relation between the diversity of caregiver speech and children's language outcomes at both syntactic levels, it is greater at a clausal level.

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In a strict sense, establishing causality requires a design in which individuals are assigned randomly to different conditions (e.g., Rogosa, 1980; Shadish, Cook, and Campbell, 2002). However, in naturalistic settings, it is not easy to manipulate the nature of the language input children receive. Thus, it is important to identify methodological approaches that minimize the possibility of alternative interpretations arising in correlational research. If studies with varying methodologies all yield evidence of a causal role of input variations in child language outcomes, it would add support to a constructivist account.

School studies offer a potential way to explore input from biologically unrelated providers as a contributing factor to language growth. One large scale study of kindergarten and first grade children showed differentially greater language growth in the same children over the school year than over the summer (Huttenlocher, Levine, and Vevea, 1998); another study showed that complexity of caregiver speech was correlated with children's language growth over a preschool year, but there was no correlation between caregivers and children at the beginning of the school year (Huttenlocher, Vasilyeva, Cymerman, and Levine, 2002). Finally, laboratory studies, where children are randomly assigned to differing conditions, also show that input is a causal factor in language growth, although such studies do not test a wide range of language forms or cover extended time periods (e.g., Tomasello and Brooks, 1998; Vasilyeva, Waterfall, and Huttenlocher, 2006). The combined results of these studies with differing methodologies provide strong empirical support for an account of language development in which input plays a causal role in child outcomes.

## Caregiver speech as a mediator between demographic factors and language growth

Finally, our analyses show a substantial relation of demographic factors to children's language, a relation which may be, in part, a by-product of differences in the speech of caregivers from different groups. We examined whether SES differences in child speech might be mediated by differences in the speech of their caregivers; first, we analyzed SES effects when caregiver speech was not included, and then later included caregiver speech in our analyses. SES (income) was a highly significant predictor of children's language outcomes at all three levels of diversity (lexical, constituent and clausal). However, the effect of SES was smaller when caregiver speech was included, suggesting that SES effects may be, at least partially, mediated by caregiver speech.

It should be noted that various other environmental factors also are associated with SES. For example, Rowe (2008) found that high SES caregivers had greater knowledge of child development, and that this knowledge was related to children's language growth. Indeed, recent research suggests that maternal knowledge of infant development and her engagement with the infant may partially mediate SES effects (e.g., Veron-Feagans, Pancsofar, Willoughby, Odom, Quade, and Cox, 2008).

In addition to SES, another demographic factor, first-born status, was significantly related to the clausal diversity of children's speech, consistent with prior work on birth order effects. For example, Hoff-Ginsberg (1998) showed that mothers used longer utterances with first-born than with their later-born children, and that the language of the first-borns was accelerated. Since the biological relation of parent to child does not vary over successive births, differences in language growth associated with birth order would seem to reflect environmental factors. Our analyses showed that the magnitude of the effect of the first-born status on children's clausal diversity was substantially smaller when caregivers' clausal diversity was included in the analysis, suggesting that birth order effects too may be mediated by caregiver speech. Thus, a wide range of findings in which children's language growth is associated with demographic factors may actually stem from differences in caregiver speech.

## Conclusions

In conclusion, the present study provides compelling evidence that variations in language input, notably differences in the syntactic structures caregivers use, affect children's language growth. Our study adds to the existing literature in several ways. First, we created an analytic scheme which characterizes the diversity of syntactic devices used by individuals at two syntactic levels, and specifies a set of structures at each level. Applying this scheme, we found large individual differences among caregivers and related differences among children. Our diversity measures, applied to caregivers, predicted the growth of corresponding structures in children. Second, we have reduced the ambiguities of interpretation of correlational data by using a variety of statistical techniques; notably, lagged correlations allowed us to eliminate temporary factors, and also to assess directionality in the relation between caregiver and child. Third, we systematically incorporated key demographic variables (SES, birth order, and child gender) along with linguistic analyses in our study. We found that SES effects were at least partially mediated by caregiver speech, showing the pervasive role of input in language growth. In short, the present study provides striking evidence supporting an account of language development in which inductive processes are critical to children's language outcomes.

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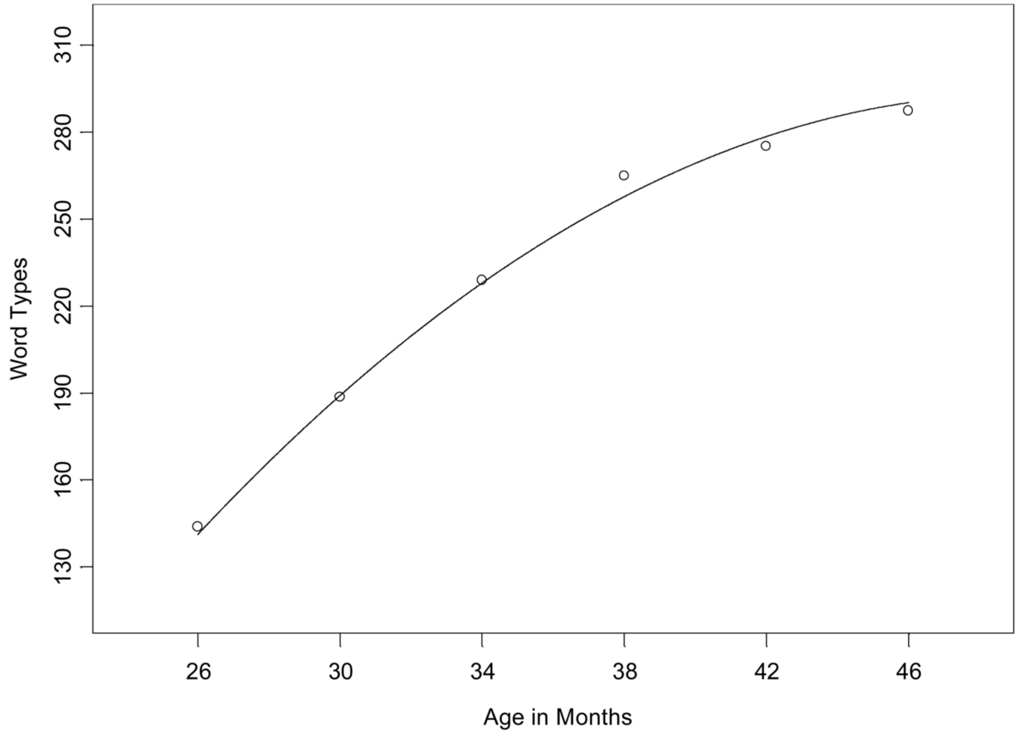


**Figure 1.**
Children's average growth trajectory for lexical diversity

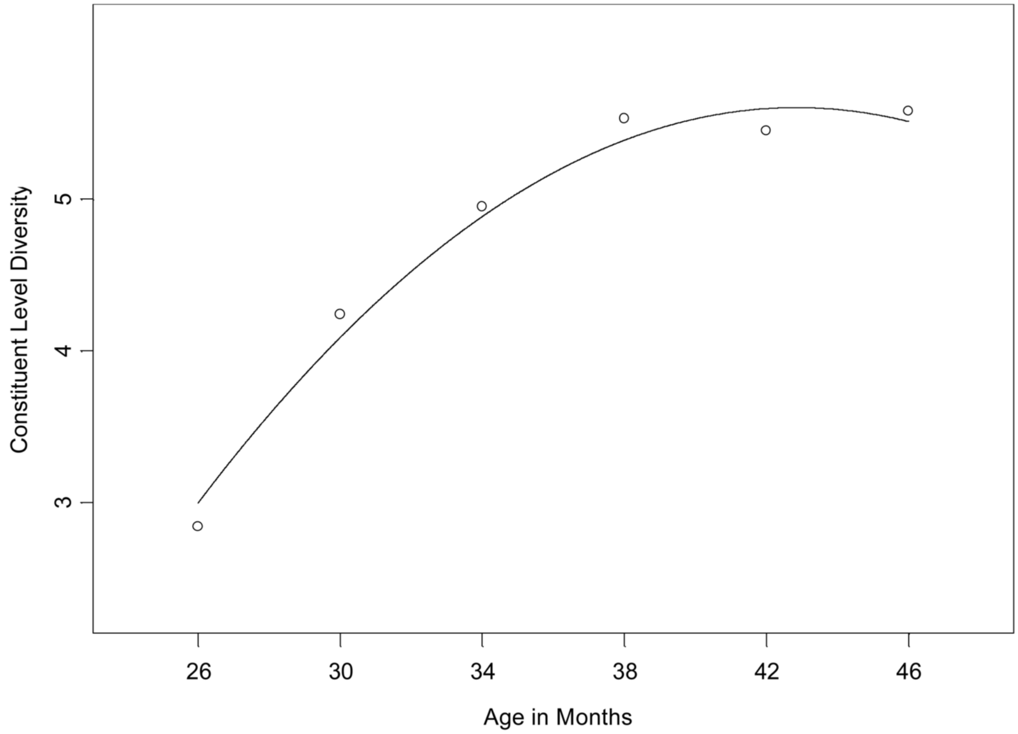


**Figure 2.**
Children's average growth trajectory for constituent diversity

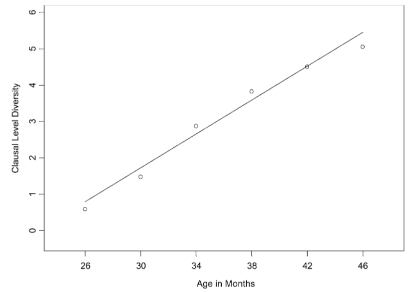


**Figure 3.**
Children's average growth trajectory for clausal diversity

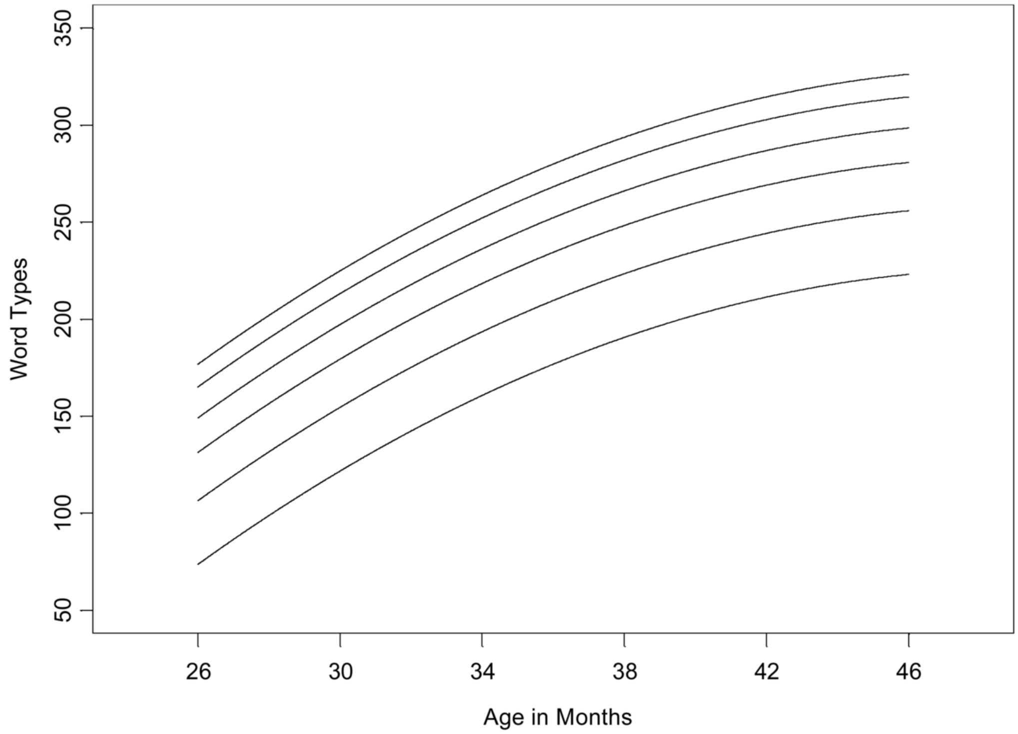


**Figure 4.**
Modeled growth curves for children's lexical diversity as a function of SES

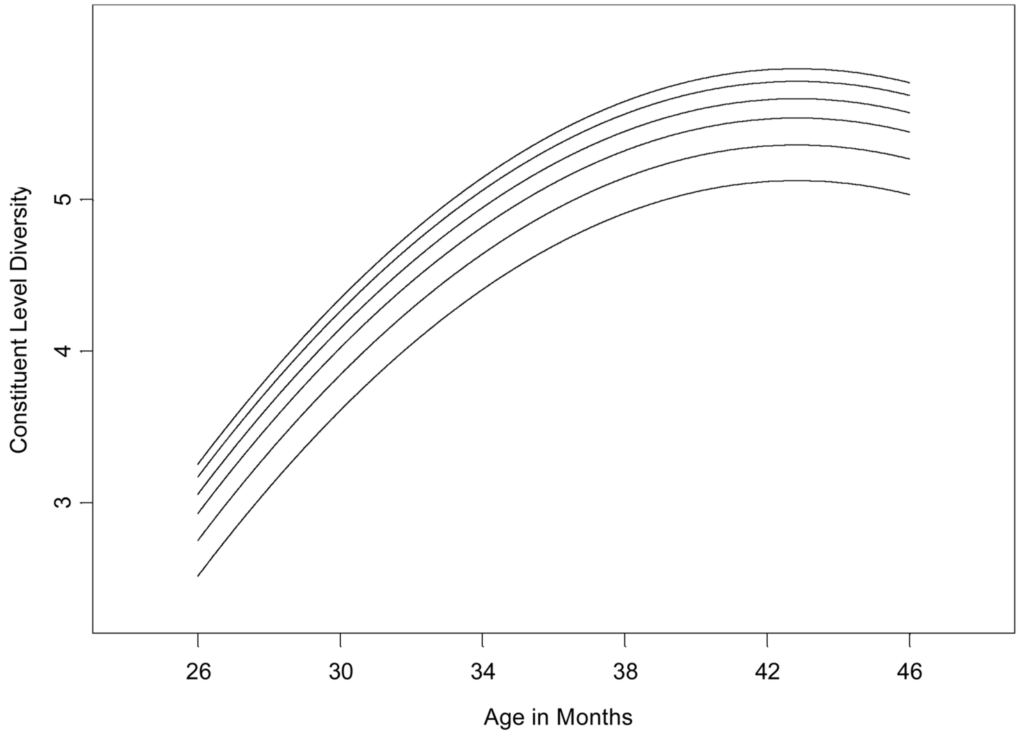


**Figure 5.**
Modeled growth curves for children's constituent diversity as a function of SES

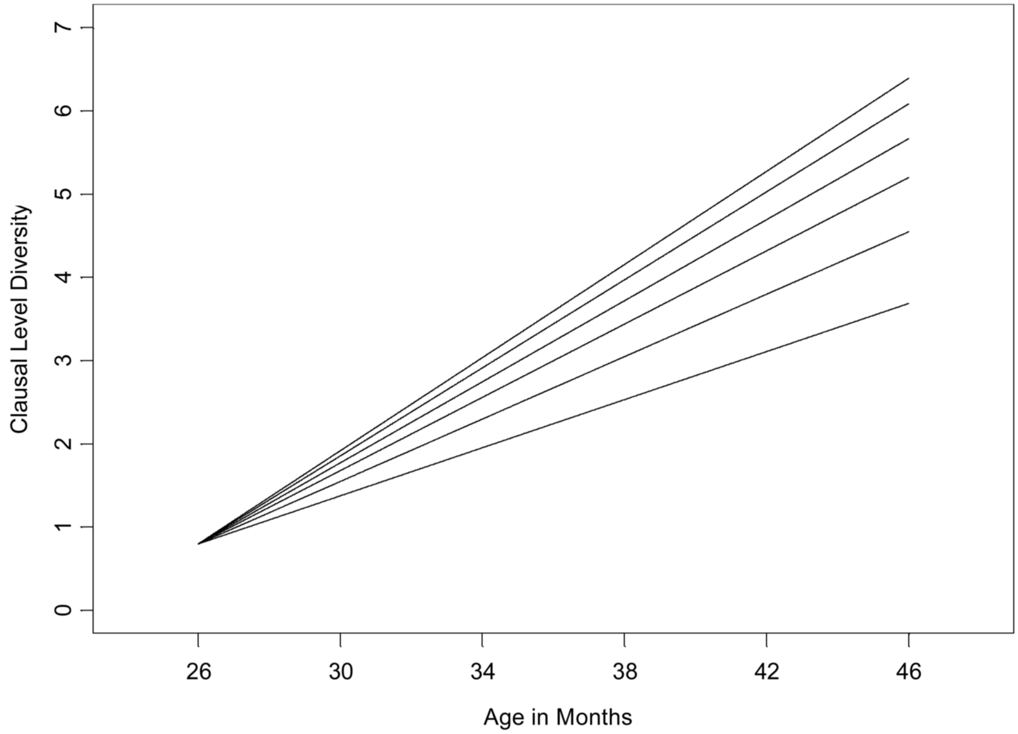


**Figure 6.**
Modeled growth curves for children's clausal diversity as a function of SES

**Table 1**

Characteristics of the sample

| Social factor | Frequency |
|---|---|
| Educational Level | |
| High school only | 5 |
| Some college | 10 |
| Bachelor's degree | 16 |
| Advanced degree | 16 |
| Income level | |
| less than $15,000 | 4 |
| $15,000 to $34,999 | 10 |
| $35,000 to $49,999 | 5 |
| $50,000 to $74,999 | 9 |
| $75,000 to $99,999 | 9 |
| $100,000 or more | 10 |
| Race/Ethnicity | |
| African-American | 9 |
| Asian | 3 |
| Hispanic | 5 |
| White | 30 |
| Birth order of target child | |
| First born | 29 |
| Later born | 18 |

## Table 2

**Table 2a Average number of utterances and diversity for children's lexical, constituent, and clausal devices by age M (SD)**

| Child Speech | Average Utterances | Lexical Diversity | Constituent Diversity | Clausal Diversity |
|---|---|---|---|---|
| 14 mo. | 29.40 (37.42) | 7.86 (8.48) | 0.06 (0.25) | 0.00 (0.00) |
| 18 mo. | 143.15 (132.49) | 31.39 (25.93) | 0.36 (0.64) | 0.00 (0.00) |
| 22 mo. | 285.28 (243.35) | 83.29 (66.76) | 1.62 (1.53) | 0.04 (0.21) |
| 26 mo. | 455.18 (262.29) | 149.27 (87.98) | 2.84 (1.92) | 0.71<br>0.93 |
| 30 mo. | 500.77 (234.47) | 191.04 (78.51) | 4.17 (1.5) | 1.57 (1.42) |
| 34 mo. | 568.87 (241.97) | 221.96 (77.4) | 4.85 (1.23) | 2.96 (1.73) |
| 38 mo. | 627.64 (197.17) | 261.11 (69.18) | 5.45 (1.14) | 3.61 (2.12) |
| 42 mo. | 578.74 (175.71) | 276.00 (74.55) | 5.44 (0.91) | 4.48 (2.41) |
| 46 mo. | 575.70 (280.73) | 283.49 (97.46) | 5.59 (1.19) | 5.09 (3.22) |

**Table 2b Average number of utterances and diversity for caregivers' lexical, constituent, and clausal usage by child age: M (SD)**

| Caregiver Speech | Average Utterances | Lexical Diversity | Constituent Diversity | Clausal Diversity |
|---|---|---|---|---|
| 14 mo. | 820.75 (419.10) | 335.50 (112.7) | 6.23 (1.18) | 6.62 (3.02) |
| 18 mo. | 846.49 (433.027) | 341.15 (115.04) | 6.34 (0.96) | 7.24 (3.92) |
| 22 mo. | 767.36 (407.76) | 351.29 (120.23) | 6.38 (0.86) | 7.76 (4.06) |
| 26 mo. | 804.13 (407.67) | 375.64 (123.12) | 6.42 (0.97) | 9.16 (4.83) |
| 30 mo. | 808.22 (394.34) | 402.26 (111.24) | 6.35 (1.06) | 11.02 (4.92) |
| 34 mo. | 724.06 (404.38) | 395.17 (136.74) | 6.55 (0.75) | 11.40 (5.14) |
| 38 mo. | 778.47 (452.44) | 413.00 (125.94) | 6.68 (0.67) | 11.04 (5.01) |
| 42 mo. | 747.54 (406.38) | 420.04 (140.71) | 6.50 (0.89) | 12.94 (5.14) |
| 46 mo. | 616.40 (457.36) | 383.51 (157.93) | 6.20 (1.06) | 12.29 (6.77) |

## Table 3

**Table 3a Children's uses of particular constituent devices by age: M (SD)**

| Child Speech | adv | adj | pp | adv+ | poss | np | class | total |
|---|---|---|---|---|---|---|---|---|
| 14 mo. | 0.09 (0.46) | 0.13 (0.65) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.21 (0.78) |
| 18 mo. | 1.13 (3.54) | 2.32 (8.59) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.26 (1.48) | 0.00 (0.00) | 3.70 (9.33) |
| 22 mo. | 8.53 (15.99) | 7.60 (12.62) | 0.27 (0.81) | 0.13 (0.50) | 0.09 (0.36) | 0.09 (0.36) | 0.02 (0.15) | 16.73 (24.47) |
| 26 mo. | 28.31 (30.12) | 13.42 (13.19) | 3.38 (6.22) | 0.69 (1.26) | 0.71 (1.29) | 0.27 (0.99) | 0.02 (0.15) | 46.80 (44.80) |
| 30 mo. | 44.24 (38.30) | 16.70 (10.93) | 6.50 (8.80) | 1.46 (2.23) | 0.63 (1.40) | 0.52 (0.84) | 0.26 (0.68) | 70.30 (55.70) |
| 34 mo. | 52.43 (33.77) | 23.30 (14.71) | 11.68 (11.01) | 2.70 (4.41) | 1.11 (1.66) | 1.15 (2.35) | 0.49 (0.93) | 92.85 (52.48) |
| 38 mo. | 63.60 (39.62) | 28.72 (14.37) | 16.49 (11.45) | 4.72 (5.45) | 1.26 (1.97) | 1.28 (1.60) | 0.91 (2.00) | 116.98 (62.04) |
| 42 mo. | 60.83 (33.33) | 27.28 (12.74) | 18.98 (14.46) | 7.39 (6.94) | 1.96 (2.93) | 1.41 (1.77) | 0.85 (2.35) | 116.98 (62.04) |
| 46 mo. | 69.37 (41.18) | 31.15 (20.14) | 22.52 (17.68) | 9.78 (10.76) | 1.22 (1.69) | 1.43 (1.71) | 1.13 (1.87) | 136.61 (79.61) |

**Table 3b Caregivers' uses of particular constituent devices by age: M (SD)**

| Caregiver Speech | adv | adj | pp | adv+ | poss | np | class | total |
|---|---|---|---|---|---|---|---|---|
| 14 mo. | 113.87 (72.93) | 56.83 (39.75) | 38.43 (25.97) | 13.81 (14.10) | 6.94 (7.34) | 3.17 (2.58) | 2.45 (2.38) | 235.49 (142.89) |
| 18 mo. | 118.77 (80.27) | 56.66 (36.63) | 43.81 (31.71) | 12.38 (13.15) | 6.34 (6.91) | 4.02 (4.72) | 3.43 (3.85) | 245.40 (155.70) |
| 22 mo. | 103.98 (70.55) | 54.09 (32.28) | 46.58 (27.04) | 12.73 (11.46) | 5.62 (6.44) | 5.00 (4.18) | 3.47 (3.75) | 231.47 (136.24) |
| 26 mo. | 113.80 (63.67) | 59.36 (33.35) | 55.80 (32.83) | 13.84 (10.26) | 6.49 (6.31) | 5.20 (4.11) | 4.38 (4.01) | 258.87 (138.32) |
| 30 mo. | 118.65 (65.79) | 62.17 (32.51) | 56.57 (34.57) | 17.52 (12.53) | 4.91 (4.95) | 4.63 (4.20) | 5.07 (4.95) | 269.52 (140.86) |
| 34 mo. | 113.38 (71.98) | 61.96 (33.69) | 57.36 (33.58) | 18.77 (14.91) | 4.68 (4.60) | 6.32 (3.88) | 7.19 (7.41) | 269.66 (154.99) |
| 38 mo. | 119.66 (73.13) | 63.40 (35.16) | 55.68 (30.71) | 22.55 (18.17) | 5.43 (4.92) | 6.04 (5.22) | 7.11 (8.70) | 279.87 (157.38) |
| 42 mo. | 113.22 (67.04) | 65.76 (42.56) | 45.46 (33.02) | 24.57 (16.70) | 3.65 (5.16) | 4.87 (4.43) | 4.83 (5.22) | 262.35 (159.38) |
| 46 mo. | 100.53 (70.19) | 61.13 (42.33) | 48.69 (31.43) | 26.80 (22.78) | 2.11 (2.18) | 4.31 (3.70) | 4.89 (5.42) | 248.47 (165.35) |

Key: adv = adverb; adj = adjective; pp = prepositional phrase; adv+ = adverbs that modify other adjectives and adverbs; poss = possessive; np = noun phrase; class = classifier.

## Table 4

**Table 4a Children's uses of particular clausal devices by age: M (SD)**

| Child Speech | OC | CO | A2 | ORC | A1 | SC | SRC | TOTAL |
|---|---|---|---|---|---|---|---|---|
| 14 mo. | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| 18 mo. | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| 22 mo. | 0.04 (0.21) | 0.00 (0.00) | 0.00 (0.00) | 0.02 (0.15) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.07 (0.33) |
| 26 mo. | 1.13 (2.02) | 0.51 (1.12) | 0.07 (0.33) | 0.13 (0.46) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 1.84 (2.96) |
| 30 mo. | 3.41 (5.19) | 1.30 (2.29) | 0.43 (1.09) | 0.37 (1.27) | 0.02 (0.15) | 0.02 (0.15) | 0.00 (0.00) | 5.57 (7.77) |
| 34 mo. | 7.30 (7.74) | 1.98 (2.81) | 1.85 (2.81) | 1.43 (3.03) | 0.15 (0.42) | 0.02 (0.15) | 0.00 (0.00) | 12.72 (12.73) |
| 38 mo. | 11.04 (8.73) | 3.34 (4.39) | 3.23 (3.81) | 1.53 (2.26) | 0.40 (0.85) | 0.04 (0.29) | 0.02 (0.15) | 19.62 (16.77) |
| 42 mo. | 13.98 (10.15) | 4.63 (4.86) | 4.11 (5.57) | 1.96 (2.10) | 0.59 (1.24) | 0.13 (0.88) | 0.02 (0.15) | 25.41 (19.39) |
| 46 mo. | 18.87 (16.15) | 6.54 (8.09) | 3.87 (4.36) | 2.37 (2.67) | 1.48 (1.99) | 0.15 (0.89) | 0.00 (0.00) | 33.28 (27.45) |

**Table 4b Caregiver's uses of particular clausal devices by age: M (SD)**

| | Clausal Form | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Caregiver Speech | OC | CO | A2 | ORC | A1 | SC | SRC | total |
| 14 mo. | 30.77 (20.91) | 7.02 (6.61) | 6.66 (6.34) | 4.34 (4.24) | 0.98 (1.26) | 0.11 (0.37) | 0.02 (0.15) | 49.89 (34.48) |
| 18 mo. | 31.06 (23.56) | 7.66 (8.11) | 11.36 (10.99) | 3.57 (4.03) | 0.96 (2.03) | 0.11 (0.37) | 0.02 (0.15) | 54.74 (43.33) |
| 22 mo. | 30.42 (20.45) | 9.69 (9.16) | 14.73 (14.24) | 3.98 (3.74) | 1.76 (2.48) | 0.09 (0.36) | 0.02 (0.15) | 60.69 (42.62) |
| 26 mo. | 40.24 (25.57) | 12.38 (8.95) | 15.07 (11.72) | 5.58 (6.11) | 2.24 (2.38) | 0.22 (0.42) | 0.02 (0.15) | 75.76 (49.51) |
| 30 mo. | 49.28 (29.81) | 14.48 (9.93) | 17.54 (13.58) | 6.54 (7.11) | 3.48 (3.74) | 0.26 (0.57) | 0.09 (0.35) | 91.67 (57.58) |
| 34 mo. | 50.09 (34.32) | 14.91 (11.77) | 13.98 (9.49) | 6.85 (7.75) | 3.77 (3.13) | 0.09 (0.28) | 0.13 (0.34) | 89.81 (59.36) |
| 38 mo. | 50.02 (30.85) | 13.11 (9.32) | 12.81 (9.29) | 8.43 (6.24) | 3.98 (3.57) | 0.23 (0.48) | 0.21 (0.46) | 88.79 (53.56) |
| 42 mo. | 51.91 (27.38) | 17.28 (10.85) | 14.78 (9.76) | 9.09 (7.59) | 4.13 (3.46) | 0.28 (0.66) | 0.15 (0.36) | 97.63 (53.06) |
| 46 mo. | 51.00 (35.10) | 15.67 (12.18) | 17.96 (12.21) | 7.91 (7.10) | 5.24 (4.65) | 0.49 (0.99) | 0.29 (0.51) | 98.56 (67.18) |

Key: OC = Object Clause; CO = Coordination; A2 = Adjunct Clause 2nd; ORC = Object Relative Clause; A1 = Adjunct Clause 1st; SC = Subject Clause; SRC = Subject Relative Clause.

**Table 5**

Tests for shapes of change trajectories

| Measure | $t_{46}$ statistic for linear change | $t_{46}$ statistic for quadratic change |
|---|---|---|
| Lexical Diversity | 8.90*** | −3.68*** |
| Constituent Diversity | 7.61*** | −5.52*** |
| Clausal Diversity | 6.85*** | −1.73 |

*Key: $p < .050$.

**$p < .010$.

***$p < .001$.

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**Table 6**

Standard deviations for growth components

| Measure | Intercept *SD* | Intercept $\chi^2_{46}$ | Linear Slope *SD* | Linear Slope $\chi^2_{46}$ | Quadratic Slope *SD* | Quadratic Slope $\chi^2_{46}$ |
|---|---|---|---|---|---|---|
| Lexical Diversity | 83.4 | 314.3$^{***}$ | 24.4 | 81.1$^{**}$ | 5.8 | 94.2$^{***}$ |
| Constituent Diversity | 1.66 | 214.3$^{***}$ | 0.76 | 88.6$^{***}$ | 0.1 | 64.2$^{*}$ |
| Clausal Diversity | 0.5 | 51.7 | 0.45 | 129.3$^{***}$ | --- | --- |

$^{*}$*Key:* $p < .050$.

$^{**}$$p < .010$.

$^{***}$$p < .001$.

**Table 7**

Stability of Child speech over time: Kendall's coefficient of concordance

| Measure | Kendall's *W* | $F_{36.7,183.3}$ |
|---|---|---|
| Lexical Diversity | 0.67 | 10.13*** |
| Constituent Diversity | 0.38 | 3.10*** |
| Clausal Diversity | 0.65 | 9.47*** |

*** *Key*: $p < .001$

## Table 8

**Table 8a Correlations among caregiver measures averaged over time**

| | Lexical Diversity | Constituent Diversity | Clausal Diversity | Frequency of Speech |
|---|---|---|---|---|
| Lexical Diversity | 1 | | | |
| Constituent Diversity | 0.63 | 1 | | |
| Clausal Diversity | 0.76 | 0.53 | 1 | |
| Quantity of Speech | 0.93 | 0.56 | 0.74 | 1 |

**Table 8b Correlations among child measures averaged over time**

| | Lexical Diversity | Constituent Diversity | Clausal Diversity | Frequency of Speech |
|---|---|---|---|---|
| Lexical Diversity | 1 | | | |
| Constituent Diversity | 0.70 | 1 | | |
| Clausal Diversity | 0.71 | 0.60 | 1 | |
| Quantity of Speech | 0.89 | 0.65 | 0.73 | 1 |

Note: all of the individual correlations at particular times that were averaged were significant at minimally the .01 level; most were significant at $p < .0001$.

Note: all but one of the individual correlations at particular times that were averaged were significant $p < .0001$; the exception was the correlation between constituent and clausal diversity at 42 months, where $p < .0004$.

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## Table 9

Log Income as a predictor of growth

| | Predicting Intercept | | Predicting Linear Slope | |
|---|---|---|---|---|
| **Measure** | **Coefficient** | | **Coefficient** | |
| Lexical Diversity | 46.9 | 3.77*** | --- | --- |
| Constituent Diversity | 0.33 | 2.07* | --- | --- |
| Clausal Diversity | --- | --- | 0.25 | 2.25* |

* *Key:* $p < .050$.

** $p < .010$.

*** $p < .001$.