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Predictors of Morphosyntactic Growth in Typically Developing Toddlers: Contributions of Parent Input and Child Sex

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Purpose: Theories of morphosyntactic development must account for between-child differences in morphosyntactic growth rates. This study extends Legate and Yang's (2007) theoretically motivated cross-linguistic approach to determine if variation in properties of parent input accounts for differences in the growth of tense productivity.
Method: Fifteen toddlers (and parents) participated. None were producing tense morphemes productively at 21 months. Two dependent measures of morphosyntactic growth between 21 and 30 months were used: empirical Bayes linear coefficients at 21 months and predicted productivity scores at 30 months. Predictor variables included child sex, vocabulary, and mean length of utterance as well as 4 measures of parent language input at 21 months.

Results: Input informativeness for tense was the most consistent predictor of morphosyntactic growth, explaining 28.3% of the unique variance in children's linear growth coefficients at 21 months and 23.0% of the unique variance in predicted tense productivity scores at 30 months. General input measures were unrelated. Child sex explained an additional 24.7% of the variance in early linear growth. Child vocabulary at 21 months did not explain a significant proportion of unique variance.
Conclusion: The findings provide evidence that *input informativeness,* an abstract and distributed property of input, contributes to morphosyntactic growth.

Key Words: grammar, morphosyntax, tense, input, acquisition

Children's acquisition of tense marking is a central phenomenon that must be explained in any adequate theory of language acquisition. In many languages, it has been well-documented that children's early sentences lack tense, with children producing nonfinite verb forms in contexts where adults would produce finite forms (Guasti, 2002). There is also longitudinal evidence that children acquire tense gradually (Blom & Wijnen, 2006; Rice, Wexler, & Hershberger, 1998; Rispoli, Hadley, & Holt, 2009). Competing theoretical frameworks have generated a variety of explanations for why these non-adult-like sentences appear (Freudenthal, Pine, & Gobet, 2009; Legate & Yang, 2007; Tomasello, 2003; Wexler, 1998) with vast differences in the emphases each framework places on biological, environmental, and developmental factors. In contrast, less attention has been directed toward understanding the way in which these factors interact to account for between-child differences in the rate of morphosyntactic growth. To improve early identification of young children at risk for language impairment and to design more effective interventions for them, it is crucial to understand how biological factors, developmental readiness, and properties of adult input interact to support morphosyntactic learning.

In a classic study, Huttenlocher, Haight, Bryk, Seltzer, and Lyons (1991) examined predictors of children's vocabulary growth during the rapid period of acceleration from 14 to 26 months of age. Hierarchical linear modeling (HLM; cf. Raudenbush & Bryk, 2002; Raudenbush, Bryk, & Congdon, 2007) was used to characterize individual differences in children's vocabulary growth trajectories and to evaluate the extent to which parent input and child sex could account for the between-child differences observed. Huttenlocher et al. (1991) demonstrated that both parents' vocabulary diversity at 14 months and child sex were significant predictors. Importantly, the sex differences could not be reduced to differences in the parents' lexical diversity directed to boys versus girls. This study showed that properties of parent input and child

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sex both influenced children's vocabulary growth independently of one another. In addition, it made important methodological advances. The growth modeling approach provided a means of evaluating predictors of developmental growth, not a static outcome at a single point in time. It also demonstrated that a relatively small sample size ($n = 22$) could reveal theoretically important relationships when effect sizes are large.

In comparison to the study of early vocabulary development, fewer studies have investigated predictors of between-child variation in morphosyntactic growth. Recently, Hadley and colleagues (Hadley & Holt, 2006; Hadley & Short, 2005; Rispoli et al., 2009) developed an approach for measuring the onset of morphosyntactic growth. Rispoli et al. (2009) argued that documentation of individual variation in morphosyntactic growth was a necessary prerequisite to investigating predictors of typical and atypical growth. Rispoli et al. (2009) also used HLM to characterize group trends and to estimate individual tense productivity growth trajectories for 20 typically developing children between 21 and 30 months of age. They found that a quadratic growth model, centered at 21 months of age, with no intercept was the best fit to the data. However, growth in tense productivity was apparent immediately thereafter, as reflected by an average linear slope at 21 months of 0.581 with gradual overall acceleration between 21 and 30 months. Significant variation was also apparent between children in both linear slopes and overall acceleration. These quantitative findings provided converging evidence for Radford's (1990) corpus analyses documenting the absence of productive tense marking around 21 months of age followed by its emergence around the second birthday.

In this study, we considered three sources of influence on children's morphosyntactic growth: biological, developmental, and environmental. Child sex is a complex variable, entailing biological differences as well as the influence of sex on developmental readiness and the potential for differences in environmental experiences. Sex differences in vocabulary development are well established. Huttenlocher et al. (1991) and Bauer, Goldfield, and Resnick (2002) demonstrated more rapid vocabulary growth for girls than boys. By age 2 years, both longitudinal and cross-sectional sources estimate a 100-word advantage for the average girl relative to the average boy (i.e., 50th percentile; Fenson et al., 2007; Huttenlocher et al., 1991). Therefore, it is reasonable to investigate the influence of sex on the growth of morphosyntax.

Claims have also been made about the contribution of developmental variables such as vocabulary abilities to growth in morphosyntax. Cross-lag correlational designs were first used to argue that there is "much continuity from first words to grammar" (Bates, Bretherton, & Snyder, 1988, p. 264). This continuity view gave rise to the *critical mass hypothesis* (Marchman & Bates, 1994), which proposed that the "development of closed-class vocabulary may require the presence of a certain critical mass of nouns, verbs and other content words" (Bates et al., 1994, p. 98). More recently, the strong version of this hypothesis has been tempered. Dixon and Marchman's (2007) new analyses did not reveal the temporal priority of lexical development over grammatical development. Rather, they concluded that the lexicon and the grammar develop simultaneously, and they speculated that some other underlying variable—such as the input that children hear (p. 206)—may, in fact, support the development of both domains. Empirically, there is enormous variation in children's vocabulary abilities. That is, the average vocabulary range at age 21 months spans from 50 words to more than 300 words (15th to 85th percentiles; Fenson et al., 2007). It remains an open question as to whether variation in vocabulary development accounts for subsequent variation in children's rate of morphosyntactic development.

Finally, we were interested in the extent to which variation in language input can account for morphosyntactic growth. It is generally acknowledged that children learn the grammar of their native languages implicitly as they interact with more competent speakers of the language; however, few studies have documented and replicated precise relationships between specific properties of input and children's acquisition of grammatical systems (cf. Valian, 1999). To date, only very general measures with tenuous theoretical links to children's morphosyntactic development have been examined. Based on her perception of an overwhelming array of null findings from input studies, Valian (1999) wrote:

> [We] can conclude that investigators have been looking in the wrong place for effects of input. We know that input has *some* effect, because children grow up to speak the language of their community. But the mystery of how children make use of input will not be elucidated by continuing to look at measures like parental MLU or parental verbs per utterance. (p. 511)

Valian called for theoretically motivated measures in future research, not ones that were simply easy to measure. In this study, we have addressed her concern directly by adopting and evaluating a theoretically motivated measure of language input (Legate & Yang, 2007).

We were drawn toward Legate and Yang's (2007) cross-linguistic explanation for variation in the acquisition of tense because their *variational learning approach* integrates a theory of the learner's initial state with an explicit theory of learning, acknowledging a prominent role for input. In particular, variational learning makes specific predictions about the learning mechanisms that children use and the kinds of linguistic data that they need to learn the adult grammar of their language. Its initial hypothesis space, which is constrained by universal grammar (UG), is also compatible with our *gradual morphosyntactic learning* (GML) account (Rispoli & Hadley, in press; Rispoli et al., 2009). Within the GML framework, we assume that children have some innate knowledge at their disposal to organize the language input. Similar to Pinker and Jackendoff (2009), we assume that the principles of UG give children tools to build grammar. For example, GML assumes that children have at their disposal the distinctions between predicate versus argument versus adjunct (Van Valin, 2009), which guide the learning of clause structure. GML assumes that the principle of structure dependence (Crain & Nakayama, 1987; Rispoli, 1994) also guides the learning of the phrasal and clausal relationships. A constrained hypothesis space is necessary for the acquisition of tense in light of the cross-linguistic variation in its expression. Tense must have scope over a constituent. Interestingly, there are languages, such as Guarani, that have tense with scope over a noun phrase as well as tense marking of clausal scope (Nordlinger & Sadler, 2004). To guide the child in learning what scope the tense morpheme has, the child will need to know what counts as a clause and what does not. Using knowledge of clausal structure and structurally dependent representations, children can then relate morphemes that appear in diverse syntactic contexts to one another because they are in complementary distribution. Sensitivity to this distributed evidence forms the basis of morphosyntactic learning.

In the next section, we present Legate and Yang's (2007) theoretical framework and describe their learning algorithm. Central to the variational learning approach is the a priori linguistic analysis of what verb forms in the input data provide unambiguous evidence for tense or ambiguous evidence for tense in a language. We refer to their construct (i.e., the proportion of unambiguous evidence for tense) as *input informativeness* for tense, and we review its empirical cross-linguistic support. We then introduce our rationale for extending it to the study of individual variation within English.

Variational Learning

Legate and Yang's (2007) approach to the acquisition of tense is grounded in Yang's (2002, 2004) more general model of variational learning. The approach is constrained by UG and regards statistical learning as the central mechanism driving developmental change. For Legate and Yang, the hypothesis space is also constrained by innate and domain-specific principles of linguistic structures. Structure dependence is central to their approach, guiding the learner to recognize that syntactic operations are defined over specific types of representations such as constituents and phrases and not over linear strings of words or other logical possibilities. Thus, learning is innately guided, with UG instructing the learner how to organize the language input. In contrast, the learning mechanism assumed by Legate and Yang is domain general. Learning is viewed as a competition between parameter values circumscribed within UG—in this case, a grammar with obligatory tense marking, such as Spanish, French, or English (+Tense), or without tense marking, such as Mandarin or Thai (–Tense). Learning is the result of a probabilistic algorithm that rewards and punishes competing grammars as children sift through the relevant evidence in the language input. Initially, the competing grammars have an equal probability (i.e., .50) of being selected by the learner to analyze input sentences. For each input sentence *s,* the learner with a probability P_i selects a grammar G_i and analyzes *s* with G_i. If the analysis is successful, G_i is rewarded by increasing P_i. If the analysis is unsuccessful, G_i is punished by decreasing P_i. The competing grammar G_j is adjusted in the opposite direction. In other words, attempts to analyze input sentences such as "*The baby needs a nap.*" with the target grammar (+Tense) will be rewarded. This increases the probability that the +Tense grammar will be selected on future trials and decreases the probability weight of the –Tense grammar. Alternatively, if the learner selects the competing grammar (–Tense) and attempts to analyze the same sentence, the –Tense grammar would be punished. However, if the learner selects the competing grammar (–Tense) and attempts to analyze input sentences such as "*You need a nap.*" or "*Go get your shoes.*"—which lack overt marking of Tense—this analysis would also be successful. In these instances, the –Tense grammar is rewarded, and the target grammar is punished. As such, it is predicted that input containing lots of ambiguous evidence where surface verb forms are identical to nonfinite verb forms would slow down the learning of a +Tense grammar. Finally, the variational learning model allows for differences in learner aptitude (i.e., γ) or the amount of change on each learning trial. Differences in γ reflect endogenous between-child differences. Although Yang (2002) does not address the source of these endogenous differences, γ could reflect normal variation in learning efficiency in the population or variation in biological maturation, developmental readiness, and so forth.

In summary, variational learning is a model of implicit learning that operates statistically, embedded within a UG-constrained hypothesis space. Yang (2004) argued elsewhere that statistical learning mechanisms are particularly powerful when working in a constrained hypothesis space but are insufficient when working without one. Similar to the GML account, the learning objective is the acquisition of a morphosyntactic system, not individual morphemes. The model's probabilistic learning algorithm is also consistent with the empirical observation of gradual morphosyntactic growth for tense productivity under the age of 3 years (Rispoli et al., 2009) and obligatory use of tense marking between the ages of 3 and 8 years (Rice et al., 1998). The variational learning model makes several unique predictions as well. First, it claims that the relevant input for grammatical learning is abundant. Every verb form spoken by a caregiver provides material from which the child can learn. Second, the model predicts that the rate of acquisition will be influenced by the combination of both overt and ambiguous evidence rewarding and punishing the target and competing grammars. In fact, Legate and Yang (2007) claim that "the speed with which a target grammar rises to dominance is correlated with its competitor's penalty probability" (p. 321). Finally, the model incorporates differences in both learner aptitude and input properties and, as such, can allow for different factors to explain variation in developmental rate between groups (typical vs. atypical) and within groups (variation in typical learners, variation in atypical learners).

Legate and Yang (2007) demonstrated the plausibility of their model by cross-linguistic comparisons among the input informativeness of Spanish, French, and English. They showed that Spanish was more informative than French and that French was more informative than English. Then, they showed that input informativeness across the three languages corresponded to the average ages of acquisition of the tense systems in these languages. Children learning languages with abundant overt marking (e.g., Spanish) have been observed to master obligatory marking at younger ages than English-speaking children who hear proportionately less overt marking of tense. However, there are limitations to their demonstration. Legate and Yang characterized input informativeness for each language by aggregating verb forms spoken by multiple parents and collapsing data across long stretches of development time. Their estimates of input informativeness show variation across languages, but they do not show variation within a language across multiple speakers.

Additional cross-linguistic evidence for a relationship between the morphology of verb forms in the input and root infinitive production by children has been presented by Kupisch and Rinke (2007). They studied differences in parent input and child root infinitives in Italian, Portuguese, French, English, and German. Eight dyads were selected for each language, and all children were between 2;0 and 2;2 (years;months). However, they too aggregated their data and did not explore relationships at the level of the individual parent–child dyad. Because these cross-linguistic investigations were collapsed across parents, it remains an open question as to whether there is enough variation among parents speaking the same language to account for the within-language variation observed in children's rate of morphosyntactic growth. In this study, we extended Legate and Yang's (2007) model to explore variation in input informativeness for tense in a sample of English speakers. The purpose of this study was to investigate whether variation in English parent input informativeness could account for between-child differences in morphosyntactic growth rates. The specific research questions are as follows:

1. What is the relationship between input informativeness and general measures of parent input?
2. What is the relationship among parent input, children's developmental abilities, and children's subsequent growth in tense productivity?
3. Do child sex, prior developmental abilities, and/or parent input informativeness account for unique variance in children's subsequent growth of tense productivity?

Method

Participants

Children and their families were selected from an existing longitudinal database. All participants were from DeKalb County, Illinois. Families were originally recruited for a study of young children's sentence production (Rispoli, Hadley, & Holt, 2008). Interested parents completed a brief phone interview to establish that the child participant was developing typically. We inquired about general health, pre-maturity or trauma at birth, prolonged hospitalization, otitis media, developmental milestones, talkativeness, and intelligibility. If parents reported frank neurological or sensory impairments, repeated bouts of otitis media resulting in the insertion of pressure-equalizing tubes, or delayed onset of walking or talking (i.e., after 15 months), their children were not invited to participate in the study. Informed consent was also obtained for subsequent studies of language development using the archival database.

The archival database contains audio recordings and transcripts for two 1-hr naturalistic parent–toddler play sessions spaced no more than 2 weeks apart at 21, 24, 27, 30, and 33 months of age. Dyads were selected for the present study from the 19 families that participated in the first four measurement points used. One dyad was excluded because the parent was a non-native speaker of English. Three additional dyads were excluded because the children had tense productivity scores ≥ 1 at 21 months. Children with productivity scores ≥ 1 were excluded to reduce the potential for parent input to be influenced by their children's use of tense morphemes. The final sample of 15 toddlers and their parents included seven girls and eight boys, 13 mothers, and two fathers. Fourteen of the child participants were White; one was African American. Measures of general language development were used to confirm the children's typical language status at 30 months and to determine whether the sample reflected a range of language abilities. For further details, interested readers are referred to Rispoli et al. (2008, 2009).

Procedure

For our prior study of children's morphosyntactic growth, one of the two sessions from each of the 21-, 24-, 27-, and 30-month measurement points was randomly selected (see Rispoli et al., 2009). For the present study, the same sample at 21 months was used to characterize the children's expressive vocabulary abilities and their abilities to combine words as potential predictors of subsequent morphosyntactic growth. The other session at 21 months was used to characterize parent input. For two dyads, only one full session was available. In one case, the second session was lost due to a technical difficulty; in the other case, the family chose to end a session early. Thus, with the exception of these two sessions, our measures of child and parent language were drawn from independent samples.

During the sessions, children talked with their primary caregiver, typically their mothers, while playing in a lab playroom furnished with age-appropriate toys. Occasionally, the other parent or an extended family member accompanied the child to the lab, resulting in triadic interactions. Parents were instructed to talk with their child as they would at home. Conversation was recorded on CD. A research assistant (RA) observed from a corner of the playroom and took notes about the nonverbal context. The RA kept interaction with the family to a minimum but responded if addressed by the child or parent.

Each play session was transcribed in its entirety using the standard conventions for the Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 2000). Rispoli and colleagues (2008, 2009) provide a detailed description of the child transcription process. The average agreement for child transcription was acceptable, *M* = 0.92, *SD* = 0.03. Classification of morpheme uses as productive or not productive resulted in Cohen's kappas (κs) of .85 and .91. For the present study, an additional transcription pass focused on parent speech. Four trained transcribers, unfamiliar with the hypothesis of the present study, used the original recordings and electronic transcripts to ensure complete and accurate transcription of all parent utterances. Because parent speech had not been the focus of prior studies, transcribers were instructed to add or modify any utterances as appropriate following conventional SALT procedures.

Parent Input Measures

All child-directed, spontaneous, complete, and intelligible parent utterances in the first 30 min were coded to obtain general measures of lexical diversity, mean length of utterance in morphemes (MLUm), and input informativeness for tense. Although some studies of parent input have used longer samples (e.g., Huttenlocher et al., 1991; Huttenlocher, Vasilyeva, Waterfall, Vevea, & Hedges, 2007; Newport, Gleitman, & Gleitman, 1977), 30 min is comparable to that used by others (e.g., Barnes, Gutfreund, Satterly, & Wells, 1983; Scarborough & Wycoff, 1986). Some investigators have allowed the length of time to vary and have controlled the sample size (i.e., 100 maternal utterances; Furrow, Nelson, & Benedict, 1979), whereas others have allowed both sample size and length of time to vary (Hoff, 2003). We anticipated that 30 min would be ample for estimating basic properties of parent input (i.e., verb forms in simple sentences).

The analysis of child-directed parent speech followed standard conventions in the literature (e.g., Barnes et al., 1983; Hoff, 2003; Huttenlocher et al., 1991, 2007). We excluded nonspontaneous utterances such as singing or book reading so that we could estimate the variation in verb forms that was characteristic of parents' spontaneous conversational interactions. And, finally, fully intelligible and complete utterances were used to ensure accurate coding of verb forms. Parent utterances were highly intelligible (% intelligible: *M* = 96.5, *SD* = 3.3, range = 88%–100%). Very few contained stalls and/or revisions (% disruptions: *M* = 1.3, *SD* = 1.1, range = 0%–4.4%) or were abandoned (% incomplete: *M* = 0.3, *SD* = 0.3, range = 0%–1%).

All inflectional morphemes and contractions were marked using conventional SALT procedures. The accuracy of the transcript coding was ensured by a series of computerized checking procedures completed by a second coder. Three general input measures were computed from complete and intelligible parent utterances (Hoff & Naigles, 2002; Huttenlocher et al., 2007): (a) number of utterances (NumUtt), (b) number of different words (NDW), and (c) MLUm. Although these general measures appear to capture the data-providing properties relevant to vocabulary development, we did not expect them to bear a strong relationship to children's morphosyntactic growth; they were included primarily for descriptive purposes.

To estimate input informativeness for tense, parent verb forms were coded following Legate and Yang's (2007) linguistically motivated scheme. Repetitions of parent utterances were included. That is, "*Look! Look!*" received codes for both verb forms and "*What's that? What's that?*" received codes for both uses of the copula. Tense errors on verb forms were not observed in the parent input; however, there were a few instances of agreement neutralization such as "*Where's the cows*?" or "*There's your shoes*." (i.e., *M* = 1.47, *SD* = 1.96). Although tense is marked overtly on these forms, the agreement status is equivocal. Therefore, these forms were coded as neutralizations [+T:N] and were excluded from further analysis.

Verb forms that were ambiguous for tense marking were coded as –Tense, and verb forms marked unambiguously (henceforth, overtly) for tense were coded as +Tense (for examples, see Table 1 and Appendix A). Irregular past tense verbs that do not change their surface form were coded as –Tense (e.g., *He hit* [–T] *the ball.*), whereas all other regular and irregular past tense forms were coded as +Tense (e.g., *You missed* [+T]. *You made* [+T] *a basket.*). In contrast, present tense third person singular verb forms (e.g., *It goes* [+T] *here.*) were coded as +Tense, whereas all other present tense verb forms with zero marking were ambiguous and were coded as –Tense accordingly (e.g., *I want* [–T] *some juice*. *You need* [–T] *more blocks*.). All modal auxiliaries (e.g., *can, will, should*) were coded as –Tense because they do not inflect for agreement and, arguably, do not inflect for tense (e.g., *can* vs. *could* is not a pure tense distinction). Overt uses of copula BE were coded as +Tense. Utterances with copula omissions were not coded because there was no verb form in the utterance (e.g., *you hungry?*). Overt uses of auxiliaries BE, DO, and HAVE were coded as +Tense. An auxiliary-main verb combination (e.g., *Do* [+T] *you want some juice*?) received only one code for the combination, including prohibitions (e.g., *Don't* [+T] *touch that.*). Finally, ambiguous bare verb forms were also coded as –Tense. These forms included serial verbs, bare infinitives not marked with the infinitival particle *to,* and imperatives (see Table 1). Infinitives overtly marked with *to* were not coded (e.g., *to play*), nor were small clauses (e.g., *I see* [–T] *him playing*), because these forms are distinctly nonfinite rather than ambiguous.

Although the overt and ambiguous uses previously described are dictated by the typology of English, stylistic alternatives also influenced the coding of the parent input. That is, questions addressed to a listener (e.g., *[are] you coming? [do] you want some juice?*) are grammatically acceptable with or without overt auxiliaries. When parents provided the auxiliary verb, the utterance was coded as +Tense. When parents did not provide the auxiliary, the verb form was coded as –Tense. In addition, structurally reduced utterances were also observed (e.g., *want more*?). Ambiguous verb forms in these utterances were also coded as –Tense. On rare occasions, parents provided telegraphic input (e.g., *baby need a nap*). These utterances were also coded as –Tense.

Frequency counts of all +Tense verb forms and all –Tense verb forms were computed. Input informativeness was computed as the percentage of overt +Tense forms out of total verb forms coded as +Tense or –Tense.

Reliability

We completed independent transcription reliability for adult utterances, focusing explicitly on the transcription of parent verb forms. A 5-min portion was randomly selected from each dyad's 21-month sample, was retranscribed, and was compared with the original transcript. Only fully intelligible utterances from the original transcript were scored. Composite verb constructions were treated as a single unit (e.g., *has run, doesn't want, will go, can try, will have run*). Verbal complements were treated as a second unit. All words within the unit had to be the same for the unit to be scored as an agreement. A disagreement was noted for any unit in which words or affixes were omitted or transcribed differently. Acceptable average reliability for verb form transcription was set at 80% or higher. The average agreement for adult verb form transcription was acceptable ($M = 0.85$, $SD = 0.16$); however, three samples had levels of reliability

Table 1. Coding scheme for English verb forms adapted Legate and Yang (2007).

Verb form	[–Tense]	[+Tense]
Past tense	No change irregulars (e.g., *hit, put*)	All the rest (e.g., *jumped, ate*)
Present tense	All the rest	Third person singular (e.g., *likes, has*)
Modals	All (e.g., *can, can't, should*)	
Copula		All (e.g., *is, are, was*)
Auxiliaries		
BE	Ambiguous (e.g., *__ you coming?; where __ you going?)*	Overt (e.g., ***are*** *you coming? You'****re*** *feeding the baby*.)
HAVE	Ambiguous (e.g., *I __ gotta go. I __ better go*.)	Overt (e.g., *He/****'s*** *gotta go.* ***Have*** *you finished?*)
DO	Ambiguous (e.g., *__ you want some? __you put it in there*?)	Overt (e.g., ***do*** *you want some?* ***do****n't touch that!*)
Bare stem	Ambiguous (e.g., *want more*?)	
	Imperative/affirmative (e.g., ***put*** *your shoes on;* ***let****'s put them on*.)	
	Serial verbs (e.g., *go* ***get*** *your shoes*.)	
	Bare infinitives (e.g., *let's* ***put*** *them on. You made me* ***put*** *them on*.)	
	Single words used to refer to actions (e.g., ***wiggle, eat***)	
	Telegraphic/ungrammatical (e.g., *baby* ***need*** *a nap.)*	

below 80%; therefore, the final version of these transcripts used consensus procedures. Adult utterances that could not be agreed upon were identified as partially unintelligible and were excluded from further analysis. The lower levels of reliability for these samples seemed to be related to relatively soft-spoken speech and/or rapid speech rates.

To ensure high levels of informativeness coding reliability, all coders were required to code a minimum of three practice transcripts at 90% accuracy prior to coding independently. Independent reliability for informativeness coding was conducted by the third author for two randomly selected transcripts, and classification of all +Tense and –Tense verb forms were compared, resulting in κs of .944 and .912. These kappas exceeded .80, the levels of agreement conventionally considered to be acceptable (Sprent & Smeeton, 2001).

Child Measures

Child sex was included as a biological factor in light of its unique explanation of between-child differences in vocabulary growth above and beyond the contribution of input (Huttenlocher et al., 1991). In addition, two measures of children's general language abilities at 21 months were used as developmental predictors of morphosyntactic growth. The developmental measures were based on 45 min of parent–child interaction because two children had less than 50 min at the first measurement point (i.e., M4, M11). Between-child differences in vocabulary abilities were captured by the NDW measure, and between-child differences in utterance length were captured by computing MLU in words (MLUw) to characterize children's general ability to combine words.

Two measures of child tense productivity growth served as the dependent variables for the present study. These measures were drawn from the growth models previously published in Rispoli et al. (2009). Tense productivity trajectories were derived from the longitudinal change observed in productivity scores obtained from 1-hr parent–child sessions at 21, 24, 27, and 30 months of age.[1] The calculation of the tense productivity score and the results of the growth modeling are summarized in the paragraphs that follow (cf. Hadley & Short, 2005, and Rispoli et al., 2009, respectively, for more information).

The tense productivity score is based on children's sufficiently different uses of five tense morpheme types up to a maximum score of 5 for each type. Thus, productivity scores can range from 0 to 25 for each measurement point. The morpheme types include (a) third person present singular *–s*; (b) past *–ed*; (c) auxiliary DO (i.e., *do, does, did*); (d) copula BE (i.e., *is, am, are, was, were*); and (e) auxiliary BE (i.e., *is, am, are, was, were*). To be identified as sufficiently different, verb inflections are required to appear on different lexical verbs. For copula BE, auxiliary BE, and auxiliary DO, different subject-tense morpheme combinations are required. In addition, all copula and auxiliary forms are required to be uncontracted if coupled with pronominal subjects (e.g., *that is hot!*) or *wh–* pronouns (e.g., *where did it go?*). If coupled with lexical subjects, contracted forms are permitted (e.g., *the cow's gone*). Forms contracted to pronouns (e.g., *it's allgone*) are excluded to protect against overestimating children's morphosyntactic development from potentially unanalyzed, lexically specific constructions.

The dependent variables reflecting between-child variation in children's morphosyntactic growth trajectories were taken from the growth models reported in Rispoli et al. (2009) and reproduced in Figure 1. The HLM growth models are represented by the equations in (1). These equations represent a quadratic growth model, centered at 21 months of age, with no intercept.

Repeated Observations Model (Level 1)

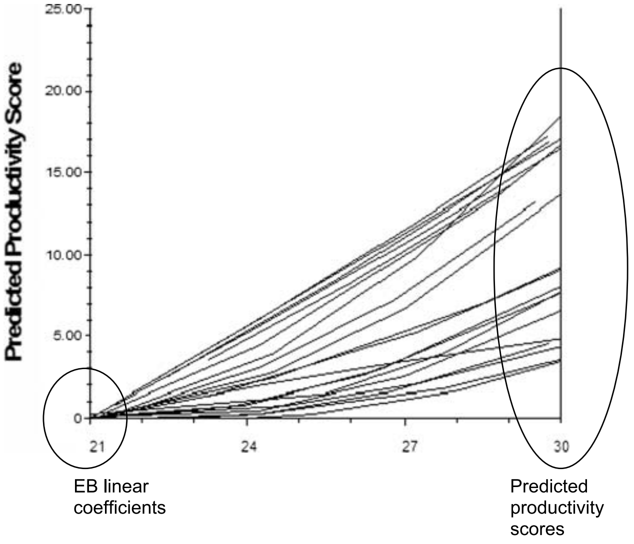
$$\mathrm{Y}_{ti} = \pi_{1i}(\mathrm{age}_{ti} - 21) + \pi_{2i}(\mathrm{age}_{ti} - 21)^2 + e_{ti} \qquad (1)$$

Person-Level Model (Level 2)

$$\pi_{1i} = \beta_{10} + r_{1i}$$

$$\pi_{2i} = \beta_{20} + r_{2i}$$

Figure 1. Growth model-based empirical Bayes (EB) estimates of the individual growth trajectories for productivity score (Rispoli et al., 2009). From "The Growth of Tense Productivity," by M. Rispoli, P. Hadley, and J. Holt, 2009, *Journal of Speech, Language, and Hearing Research, 52,* p. 938.



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[1] As previously noted, two children had less than 1 hr available in the randomly selected 21-month sample used for the child measures; however, there were no instances of tense morphemes used on the second day, either. Therefore, the shorter sample lengths did not account for the absence of tense morphemes at 21 months.

The value Y_{ti} is the observed productivity score for child i at t months, and e_{ti} is the deviation of child i from his or her growth trajectory at time t. The e_{ti} are assumed to be normally distributed with a mean of 0 and a variance of σ^2. The parameter, π_{1i}, represents the linear growth rate for child i at 21 months—that is, the linear slope tangent to each child's overall growth trajectory at 21 months where the growth model was centered. The growth parameter, π_{2i}, reflects the curvature or acceleration/deceleration in each child's overall growth. The growth parameters are made up of both fixed and random components, represented in the person-level (Level 2) model as β and r, respectively. The fixed component β reflects the average for the group. The random component r is the residual, or the individual's difference from the fixed component. Appendix B provides the empirical Bayes (EB) residuals and coefficients for each child from the Rispoli et al. (2009) growth models as well as the predicted productivity score at 30 months.[2]

The first dependent measure was the empirical Bayes (EB) linear coefficient π_{1i} (i.e., the linear slope tangent to the growth curves at 21 months; see Figure 1 and Appendix B). Children demonstrating more rapid tense productivity growth early in the developmental period would have positive residuals r_1 and, therefore, linear growth coefficients greater than Rispoli et al.'s (2009) group average of 0.581 (i.e., β_{10}). Children exhibiting slower initial growth would have negative residuals and, therefore, linear coefficients less than 0.581.

The second dependent measure was the predicted tense productivity score at 30 months, also illustrated in Figure 1. To generate a predicted tense productivity score (Y), each individual's EB residuals, r_{1i} and r_{2i}, were combined with the average linear and quadratic components, β_{10} and β_{20} (i.e., 0.581 and 0.069, respectively) from the Rispoli et al. (2009) growth model [refer to the person-level model in (1)], resulting in EB linear and quadratic coefficients π_{1i} and π_{2i}. Then, the individual's growth coefficients, π_{1i} and π_{2i}, were used in the repeated-observations model seen in (1) along with age = 30 to compute the predicted productivity score at 30 months. For example, child F13's linear growth residual r_1 at 21 months was = –0.247, resulting in a linear growth coefficient π_1 of 0.334 when combined with the average linear growth for the group of 0.581. Similarly, her quadratic growth residual r_2 at 21 months was 0.060, resulting in a quadratic growth coefficient π_2 of 0.129, when combined with the average quadratic growth for the group of 0.069. To compute her predicted productivity score at 30 months, these person-level growth coefficients were substituted into the repeated-observations model equation, yielding a predicted score of 13.46 [i.e., $(0.334)(30 - 21) + (0.129)(30 - 21)^2$]. By using predicted productivity scores at 30 months based on the four measurement points from 21 to 30 months, we captured between-child differences in their development growth over this 9-month period instead of a static measurement from the 30-month measurement point alone.

Results

Descriptive statistics revealed considerable variation in all measures of parent input (see Table 2). Input informativeness for tense varied across the 15 caregivers, ranging from 33.1% to 69.8% (M = 50.6%). Table 2 also provides the mean frequencies and *SD*s for +Tense and –Tense codes and their subcategories. The subcategories are ordered based on the relative proportion of each subcategory out of all verb forms coded (i.e., 3,741 total ±Tense codes). Imperatives, modals, and zero-marked present tense verbs were the most frequent –Tense subcategories, reflecting 18%, 9%, and 7% of all verb forms, respectively. Copula BE (primarily *is*), auxiliary DO, and auxiliary BE were the most frequent +Tense subcategories, accounting for 26%, 12%, and 7% of all verb forms, respectively.

Table 3 provides the *M*s and *SD*s for the child predictors, the productivity of each morpheme category by measurement point, and the growth-relevant dependent variables. There was considerable variability in the children's expressive vocabulary abilities, with the number of different words produced in 45 min ranging from 18 to 88 ($M = 52.20$, $SD = 24.60$). Children's MLUw ranged from 1.00 to 1.89 ($M = 1.26$, $SD = 0.25$), with the majority of children predominantly single-word users. None of the children were producing tense morphemes at age 21 months. The mean predicted productivity score was 9.52 at age 30 months. Copula BE was most productive at age 30 months, with less productivity across the other four morpheme categories. Recall that these values reflect the number of sufficiently different uses of each tense morpheme category up to a maximum of five.

To address the first research question, the general measures of parent input were examined in relation to one another and with input informativeness for tense (see Table 4). Given our small sample size, we used Spearman's nonparametric approach. The NDW that parents produced was correlated with their total number of utterances ($r_s = .576, p = .025$) and their MLUm ($r_s = .608, p = .016$). However, parents' MLUm was not related to their total number of utterances ($r_s = -.096$, $p = .732$). Parents' input informativeness was related to their MLUm ($r_s = .539, p = .038$) but not to the total number of utterances or NDW ($r_s = .021$, $p = .940$, and $r_s = .257$, $p = .354$, respectively). We then considered how the general input

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[2] Ideally, the predictors of morphosyntactic growth would have been examined within a conditional growth model; however, for this exploratory study of input informativeness, we opted to use the growth coefficients from Rispoli et al. (2009) instead of generating new growth models with a smaller subset ($n = 15$) of participants.

Table 2. Variation in parent input at children's 21-month measurement point.

Variable	Min	Max	*M*	*SD*	% verb forms
NumUtt	224	454	329.07	69.32	
NDW	146	349	227.87	47.49	
MLUm	2.68	4.77	3.70	0.50	
Informativeness	0.331	0.698	0.506	0.105	
Total verb forms	164	398	249.40	67.12	
–Tense	56	202	121.87	35.63	
–Imperative	7	77	45.07	20.44	18.1
–Modals	7	56	23.27	13.86	9.3
–Present	6	37	17.73	8.08	7.1
–Ambiguous auxiliaries	3	23	11.87	4.64	4.8
–Ambiguous	3	23	10.67	6.41	4.3
–Bare	2	17	8.47	5.01	3.4
–*Let's* imperative	0	7	2.20	2.27	1.0
–Telegraphic	0	8	1.87	1.81	0.9
–Past	0	1	0.07	0.26	< 0.01
+Tense	57	210	127.53	45.42	
+Copula	37	127	64.00	26.08	25.7
+Auxiliary DO	12	59	28.80	13.31	11.5
+Auxiliary BE	3	35	16.53	7.95	6.6
+Present	2	28	9.67	6.74	3.9
+Past	0	18	7.53	3.85	3.0
+Auxiliary HAVE	0	5	1.00	1.65	0.4

Note. Min = minimum; Max = maximum; NumUtt = number of utterances; NDW = number of different words; MLUm = mean length of utterance in morphemes.

measures related to the frequency counts of +Tense and –Tense verbs. The +Tense and –Tense components were unrelated (r_s = .179, p = .524), yet the frequency of both +Tense and –Tense verb forms was positively correlated with the number of utterances that parents produced (r_s = .568, p = .027, and r_s = .711, p = .003, respectively). Only the frequency of +Tense verb forms was related to parents' NDW and MLUm (r_s = .615, p = .015, and r_s = .514, p = .050, respectively). The frequency of –Tense verb forms was marginally related to parents' NDW and was unrelated to their MLUm (r_s = .452, p = .091, and r_s = –.086, p = .761, respectively). In sum, overt marking of tense was related to parent measures of lexical diversity and utterance length, whereas ambiguous marking was not.

To explore our second research question, we examined the relationship between the parent input measures and growth in children's tense productivity (see Table 5).

Table 3. Means and (standard deviations) for child measures by measurement point.

Measure	21 months *M (SD)*	24 months *M (SD)*	27 months *M (SD)*	30 months *M (SD)*
NDW	52.20 (24.60)			
MLUw	1.26 (0.25)			
Copula BE	0	0.73 (1.10)	2.20 (2.15)	3.73 (1.22)
Present –3s	0	0.60 (1.12)	1.27 (1.49)	1.67 (1.66)
Past –*ed*	0	0.13 (0.35)	1.33 (1.40)	1.80 (1.82)
Auxiliary DO	0	0.07 (0.26)	0.60 (1.12)	1.13 (1.69)
Auxiliary BE	0	0.33 (1.29)	0.47 (0.74)	1.00 (1.46)
Growth metrics				
EB linear coefficient	0.473 (0.733)			
Predicted productivity				9.52 (5.06)

Note. MLUw = mean length of utterance in words; EB = empirical Bayes.

Table 4. Spearman rho correlations for parent input measures.

	NDW	MLUm	Inform	+Tense	−Tense
Measure	r_s	r_s	r_s	r_s	r_s
NumUtt	.576*	−.096	.021	.568*	.711**
NDW	—	.608*	.257	.615*	.452
MLUm	—	—	.539*	.514*	−.086

Note. Inform = input informativeness.

**p* < .05. ***p* < .01 (two-tailed).

Input informativeness was positively related to both the variation in early linear growth as captured by the EB linear coefficients (r_s = .646, p = .009) and the predicted productivity score at 30 months (r_s = .746, p = .001; see Figures 2 and 3, respectively). In contrast, none of the general input measures were related to the measures of tense productivity. Analysis of the +Tense and –Tense components revealed that frequency of parents' ambiguous marking was related to slower child growth. Specifically, the frequency of –Tense forms, those that reward the nontarget grammar, was negatively related to children's EB linear coefficients at 21 months and predicted tense productivity scores at 30 months (r_s = –.746, p = .001, and r_s = –.529, p = .043, respectively), whereas the frequency of overt marking was unrelated initially and was significantly related at 30 months (r_s = .293, p = .289, and r_s = .525, p = .044, respectively).

Our final research question evaluated child sex, prior developmental abilities, and input informativeness as predictors of children's subsequent growth in tense productivity. First, independent sample t tests were used to explore potential sex differences on our dependent and independent variables (see Table 6). Although no significant sex differences were observed for either dependent measure, Levene's test for equality of variances

Table 5. Spearman rho and Pearson correlation coefficients for parent input predictors, children's developmental predictors, and outcome measures of children's tense productivity growth.

	21-month EB linear coefficients		30-month predicted tense productivity	
Variable	r_s	r	r_s	r
Parent input variables				
NumUtt	−.418	−.346	−.111	−.153
NDW	−.070	−.078	−.164	−.140
MLUm	.436	.181	.250	.145
Informativeness	.646**	.657**	.746***	.765***
+Tense	.293	.168	.525*	.336
−Tense	−.746**	−.638**	−.529*	−.533*
Developmental variables				
Child NDW	.386	.338	.606*	.635*
Child MLUw	−.054	.168	.272	.288

**p* < .05. ***p* < .01. ****p* < .001 (two-tailed).

Figure 2. Scatterplot of parent input informativeness for tense and child 21-month EB linear coefficients.

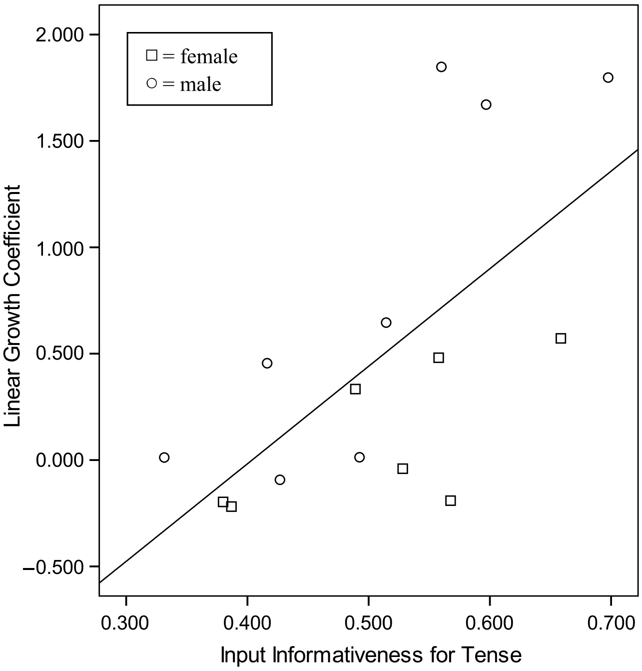

Figure 3. Scatterplot of parent input informativeness for tense and child 30-month predicted productivity scores.

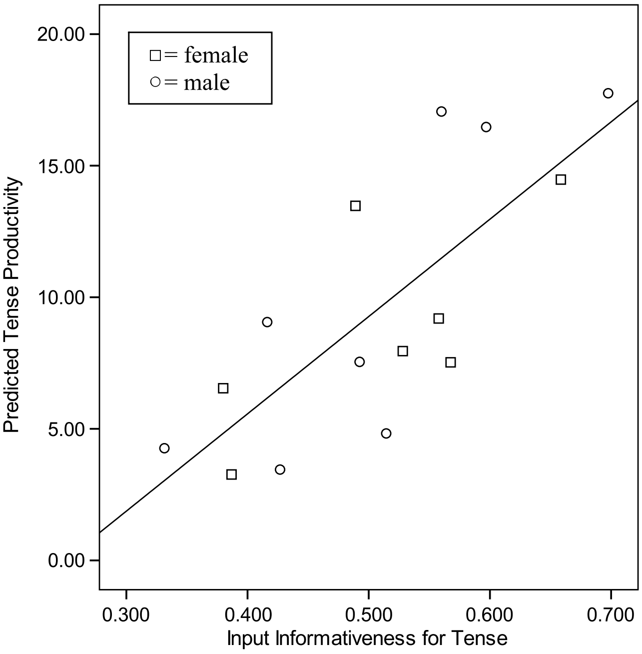

Table 6. Dependent and independent variables by child sex.

Variable	Sex	*N*	*M*	*SD*
21-month child EB linear coefficients	M	8	0.794†	0.848**
	F	7	0.106	0.345
30-month child predicted tense productivity	M	8	10.053	6.109†
	F	7	8.918	3.919
Child NDW	M	8	49.38	22.734
	F	7	55.43	28.035
Child MLUw	M	8	1.200	0.295
	F	7	1.324	0.181
Parent NumUtt	M	8	309.88	65.145
	F	7	351.00	72.176
Parent NDW	M	8	232.63	57.438
	F	7	222.43	36.724
Parent MLUm	M	8	3.735	0.394
	F	7	3.666	0.623
Parent input informativeness	M	8	0.504	0.115
	F	7	0.508	0.102

$^\dagger p < .08$. $^{**}p < .01$.

revealed a significant difference in the variances of males and females for EB linear coefficients (F = 11.322, p = .005). There were no significant differences between males and females on the two developmental predictors, child NDW and child MLUw (t = –0.462, p = .652, and t = –0.965, p = .352, respectively). Finally, there were no differences on any parent input measures at 21 months as a function of child sex (all ps $\geq$ .267). Although group differences were not apparent in input informativeness directed to males versus females, the range of informativeness to males characterized the full sample range (i.e., 33.1%–69.8%), whereas the range of informativeness to females was not as great (i.e., 38.0%–65.9%; see Figures 2 and 3). In other words, we did not find evidence for significant differences in the speech styles directed to boys versus girls that might be attributed to the cultural construct of gender.

Next, we considered whether children's 21-month NDW or MLUw was related to their morphosyntactic growth. Neither child NDW nor child MLUw was related to linear growth in tense productivity at 21 months (r_s = .386, p = .155, and r_s = –.054, p = .849, respectively; see Table 5). However, child NDW was related to predicted tense productivity scores at 30 months (r_s = .606, p = .017). No relationship was observed between child MLUw and 30-month productivity scores (r_s = .272, p = .327).

To determine the unique variance accounted for by each of our predictor variables, we conducted exploratory regression analyses with our two dependent growth variables: the EB linear growth coefficients at 21 months (Model 1) and the predicted productivity scores at 30 months (Model 2). In both models, we included child sex as a biological predictor, children's NDW as a developmental predictor, and input informativeness as an environmental input predictor (see Table 5 for zero-order correlations between the predictors and dependent variables). The three predictors accounted for 68% of the total variance in the EB linear growth coefficients (R = . 825, F = 7.804, p = .005; see Table 7). However, only child sex and input informativeness accounted for a significant proportion of unique variance in initial morphosyntactic growth (24.7% and 28.3%, respectively), reflecting potentially distinct biological and environmental contributions.

Model 2 examined the relative contributions of the predictors to children's predicted tense productivity scores

Table 7. Regression analyses predicting linear growth in productivity at 21 months and predicted productivity scores at 30 months.

					Sex	Child NDW	Inform	+Tense	–Tense
Model	*R*	*R*^{2}	*F*	*p*	*sr*	*sr*	*sr*	*sr*	*sr*
				Predictors of 21-month linear growth^a					
1	.825	.680	7.804	.005	–.497*	.028	.532*		
1a	.887	.787	9.230	.002	–.440*	.105		.344*	–.621**
				Predictors of 30-month predicted productivity scores^b					
2	.820	.673	7.550	.005	–.167	.265	.480*		
2a	.855	.731	6.804	.007	–.126	.343†		.330†	–.528**

[a]For Model 1, the dependent variable was EB linear coefficient, and the predictors were (Constant), Sex, Child NDW, and Informativeness. For Model 1a, the dependent variable was EB linear coefficient, and the predictors were (Constant), Sex, Child NDW, +Tense, and –Tense. [b]For Model 2, the dependent variable was predicted tense productivity, and the predictors were (Constant), Sex, Child NDW, and Informativeness. For Model 2a, the dependent variable was predicted tense productivity, and the predictors were (Constant), Sex, Child NDW, +Tense, and –Tense.

$^\dagger p < .08$. $^*p < .05$. $^{**}p < .01$ (two-tailed).

at 30 months. The 30-month tense productivity score is predicted using both the person-level linear and quadratic coefficients of the tense productivity growth model [recall the equations in (1)]. Model 2 was also significant, with the three predictors accounting for 67.3% of the variance in 30-month predicted scores (R = .820, F = 7.550, p = .005). Only input informativeness accounted for a significant proportion of unique variance in the 30-month predicted productivity scores (i.e., 23%).

Finally, we reevaluated Models 1 and 2 by using the two frequency measures of +Tense and –Tense together instead of the derived percentage score for informativeness. The revised four-variable models (i.e., Models 1a and 2a) had the added advantage of capturing variation in parent talkativity and provided an opportunity to further evaluate the relative contribution of overtly marked versus ambiguously marked verb forms to children's morphosyntactic growth. In Model 1a, the four variables accounted for 78.7% of the total variance in early morphosyntactic growth (R = .887, F = 9.230, p = .002). Child sex and the frequency of both +Tense and –Tense verb forms were all significant predictors of initial morphosyntactic growth (sr = –.440, p = .013; sr = .344, p = .040; and sr = –.621, p = .002, respectively), explaining 19.4%, 11.8%, and 38.6%, respectively, of the unique variance. Again, child NDW did not explain a significant proportion of unique variance (sr = .105, p = .487). In Model 2a, the four variables accounted for 73.1% of the variance in 30-month predicted productivity scores (R = .855, F = 6.804, p = .007). Model 2a also revealed the extent to which ambiguous verb forms in parent input slowed children's morphosyntactic growth. The frequency of –Tense verb forms was a significant unique predictor of children's 30-month predicted productivity scores (sr = –.528, p = .009), accounting for 27.9% of the unique variance. Child NDW and the frequency of +Tense verb forms approached significance (sr = .343, p = .062, and sr = .330, p = .071, respectively), and child sex was not a significant predictor of unique variance at 30 months of age.

Discussion

For some time, the contribution of parent language input to variation in children's morphosyntactic development has remained elusive (cf. Valian, 1999). In fact, given the absence of significant, replicable findings, Wexler (2003) remarked, "Perhaps the relevant property that makes input 'rich' has been missed" (p. 42). This study investigated a new theoretically motivated cross-linguistic measure—*input informativeness*—and extended it to the study of between-child differences in English-speaking children's morphosyntactic growth rates. Unlike prior parent input variables, input informativeness reflects a competition between overt and ambiguous evidence for tense marking on verb forms (Legate & Yang, 2007), not simply the overt expression of tense in the morphosyntax of the input language. We also examined the relative contributions of child sex and prior development to children's morphosyntactic growth. We begin this discussion by reviewing the empirical findings, followed by the theoretical implications and clinical applications of these findings for future research.

Input Informativeness Facilitates Morphosyntactic Growth

In this study, we provided a description of input informativeness at the level of the individual speaker and characterized its relationship to other more general measures of parent input. We demonstrated that variation in informativeness exists not just between languages such as Spanish and English (Kupisch & Rinke, 2007; Legate & Yang, 2007) but also between parents within a language. In this sample, parents' input informativeness varied from 33% to 70%, yet the mean input informativeness was 50.6%, a value similar to Legate and Yang's (2007) estimate for English of 52.9%. This similarity is interesting, given the differences in methodology. Legate and Yang's estimate was based on aggregate data collapsed across multiple dyads and ages. In contrast, our value reflected the mean of 15 independent parents interacting with their children at a single age. We also demonstrated that input informativeness was unrelated to parent talkativity and lexical diversity, but—as one might expect—it was moderately related to parent MLUm.

Of the four parent input variables, only input informativeness was related to children's morphosyntactic growth. It is important to note that this relevant property could have been "missed" if only the frequency of the overt forms had been considered. When the relative proportion of overt and ambiguous verb forms was considered in combination, a powerful input predictor of morphosyntactic growth emerged. Children's prior developmental accomplishments were also considered to be predictors of morphosyntactic growth. Children's ability to combine words, as measured by MLUw, was unrelated to grammatical growth. This was somewhat unexpected in light of previous studies demonstrating a relationship between children's clausal expansion and grammatical tense marking (Hadley & Holt, 2006; Rice et al., 1998); however, there was little variability in children's MLUw at 21 months of age. Children's expressive vocabulary abilities, as indexed by the NDW at 21 months, provided mixed results. Children's NDW was unrelated to our earliest measure of morphosyntactic growth (i.e., EB linear coefficients), but it was related to predicted productivity scores 9 months later. These empirical findings are compatible with Bates et al.'s (1988) demonstrated relationships between children's vocabulary abilities at 20 months of age and subsequent grammatical abilities at 28 months of age.

In our exploratory regression analyses, we examined the unique contribution of child sex, child vocabulary, and parent input informativeness for tense to children's morphosyntactic growth. Together, the three predictors accounted for more than two-thirds of the total variance in children's morphosyntactic growth, with input informativeness alone accounting for 28% and 23% in Models 1 and 2, respectively. When input informativeness was decomposed into its two frequency components (i.e., –Tense, +Tense), the four predictors accounted for approximately three-quarters of the total variance in morphosyntactic growth in Models 1a and 2a. The frequency of ambiguous and overt verb forms accounted for unique variance in initial linear growth at 21 months. In contrast, only the frequency of ambiguous verb forms (–Tense) at 21 months accounted for unique variance in 30-month tense productivity. In fact, the frequency of ambiguous verb forms explained a robust proportion of unique variance, accounting for 39% and 28% of the variance in Models 1a and 2a, respectively. Child sex accounted for a significant proportion of variance in initial linear growth only (Models 1 and 1a), and the contribution of child vocabulary was not significant in any model. It is possible that our vocabulary measure of NDW was not sensitive enough to reveal significant relationships between early vocabulary and morphosyntactic growth. In addition, early vocabulary might have been more strongly associated with morphosyntactic growth if we had not eliminated from this investigation some of our faster language learners whose productivity scores at 21 months were greater than 0. Future research with a larger sample size and children selected from the full range of language development are needed to clarify this issue.

Theoretical Implications

Variational learning. This study lends support to Legate and Yang's (2007) variational approach to morphosyntactic learning. Legate and Yang's model of UG-constrained, probabilistic learning limits the learner to two options: a +Tense grammar or a –Tense grammar. Their learning algorithm sets these two options in competition, and only gradually does the evidence from the input—in the form of overt and ambiguous verb forms—push one grammar to dominance. It is important to recognize that their approach is not a triggering account. There is no rare and/or crucial data in the input sufficient to set or reset a parameter. Rather, the input relevant for learning is abundant, with competition and probability contributing to the gradual nature of morphosyntactic development (Rispoli et al., 2009). Our findings provide new evidence that an abstract and distributed aspect of language input plays a role in the early period of morphosyntactic learning. To better operationalize the competitive nature of variational learning, we also decomposed the construct of informativeness into its two components: the frequency of +Tense verb forms and the frequency of –Tense verb forms. In fact, the combination of +Tense and –Tense frequency variables may also be a better way to capture differences in parent talkativity (Hart & Risley, 1995; Huttenlocher et al., 2007), which are relevant to "learning trials." Our findings from the four-variable regression models are well aligned with the predictions of variational learning. The early abundance of –Tense verb forms in the input had a negative impact on the +Tense grammar rising to dominance, allowing the learner to retain the –Tense grammar as an option for a longer period of time. From the perspective of variational learning, this finding requires us to reflect on the sources of ambiguous verb forms in the input. In other words, for an English language learner to converge on the target +Tense option, it appears that reducing the ambiguous verb forms early in the course of morphosyntactic learning is even more important than increasing the use of overt marking. Thus, this finding requires us to consider specific sources of ambiguous input.

At the same time, our findings pose a new challenge for variational learning as the primary explanation for children's initial production of tense morphemes. For example, if the +Tense and –Tense grammars are equally weighted at 0.50 at the beginning of morphosyntactic learning, and substantial learning takes place from analyzing input, one might expect children's first sentences to reflect more use of overtly marked forms. However, children's first sentences with lexical verbs are predominantly unmarked verb forms. Another question arises when parent informativeness values are below 50%, as was the case for seven of the 15 parents in our sample. The slim advantage of +Tense to –Tense verb forms to children's learning of English accounts for the slow rise to dominance of a +Tense grammar. Yet, how would a given learner converge on a +Tense grammar if ambiguous forms are more abundant in the input than overtly marked forms? Of course, it is possible that the empirical relationship between +Tense and –Tense forms changes as children's grammatical abilities develop; however, it seems more likely that variational learning alone is insufficient for explaining the incorporation of tense morphemes into sentence production itself.

It should also be recognized that the construct of input informativeness overlaps with some aspects of parent–child interaction style. For example, a more directive parent interaction style is associated with greater use of ambiguous forms (Fitzgerald, 2010). Imperatives were indeed the most common source of ambiguous input, accounting for 18% of all parent verb forms produced. Although less frequently occurring, other linguistic forms can also be used to direct children's behavior, such as *let's* imperatives (e.g., *let's put away the toys*) or modals (e.g., *can/will you put the toys away*?). It is certainly possible that a coding scheme based on communicative functions might have revealed a similar relationship between parent input and children's morphosyntactic growth. However, as Pine (1992) cautioned, we should be wary of "viewing interactional style as a unitary 'package' of behaviours which operates as a whole to facilitate or inhibit the child's progress in language development" (p. 173). In fact, it has been shown that parent utterances that direct children's attention versus their behavior and those that follow or lead children's attention have different relationships to child language outcomes (cf. Masur, Flynn, & Eichorst, 2005). Rather, what seems most relevant is that a directive conversational style leads to an abundance of ambigous verb forms in the input.

We have also observed that some characteristics of conversational register are associated with more ambiguous input. That is, the parents in our sample varied in the extent to which they produced *yes/no* questions with subject-auxiliary inversion (e.g., *Do you want more? Are you coming?*), without the auxiliary (e.g., *you want more? you coming?*), or without the subject and auxiliary (e.g., *want more? coming?*). Although all of these alternatives are conversationally acceptable, parents who typically produced these questions without auxiliaries received more –Tense codes, whereas parents who typically used auxiliaries in these contexts received more +Tense codes. This leads to a negative relationship between input informativeness and the percentage of *yes/no* questions that are reduced (Fitzgerald, 2010).

Finally, English-speaking parents who produce proportionately more other-focused utterances are more informative (Fitzgerald, 2010). Additionally, instructional strategies that encourage adults to shift their discourse from an interpersonal focus (e.g., *I/you put the baby to bed.*) toward a focus on the toys (e.g., *The baby needs a nap.*) result in significant increases in informativeness postinstruction (Walsh, 2010). Although awareness of this overlap in English provides us with strategies for promoting richer grammatical input, explanations for children's morphosyntactic growth based on interpersonal versus other-focused discourse topics are not likely to be valid cross-linguistically. For example, in Spanish, first, second, and third person verb forms are all overtly marked for tense. In Polish, first and second person verb forms are overtly marked for tense, whereas third person singular verb forms are not (e.g., Weist, Pawlak, & Hoffman, 2009). Thus, an other-focused discourse style in Spanish or Polish may not show the same overlap as in English.

Critical mass hypothesis. In its strong form, this hypothesis posits that a critical mass of nouns, verbs, and other content words is necessary for the acquisition of grammar. However, in our sample, between-child differences in expressive vocabulary abilities were unrelated to the earliest aspects of morphosyntactic growth. In light of the robust contribution of input informativeness to children's initial morphosyntactic growth, our findings call the strong form of the critical mass hypothesis into question. At the same time, our initial correlations indicated that early vocabulary abilities were related to later grammatical development. That is, 21-month expressive vocabulary was moderately correlated with 30-month predicted productivity scores. When we reanalyzed the relative contributions of child sex, child vocabulary abilities, and input informativeness using the frequency-based +Tense and –Tense measures, the between-child differences in expressive vocabulary were marginally significant, explaining an additional 11.8% of the variance in 30-month predicted tense productivity scores. Thus, hypotheses about the basic mechanisms of morphosyntactic learning may be enhanced by incorporating a role for developmental differences in vocabulary abilities. For example, children with large vocabularies at the onset of morphosyntactic learning should have an advantage in comprehension or in processing language input (Fernald, Marchman, & Hurtado, 2009; Fernald, Perfors, & Marchman, 2006) and could conceivably use this advantage to discover morphosyntactic regularities more readily (Blom & Wijnen, 2006; Lew-Williams & Fernald, 2007).

Gradual morphosyntactic learning. The present findings are also compatible with the assumptions of GML (Rispoli & Hadley, in press; Rispoli et al., 2009). From the GML perspective, the child's first task in learning the system of tense and agreement is apprehending the presence of tense morphemes in the language input. By using the term *apprehend,* we mean the following: the point at which competition between grammars becomes clearly biased toward the +Tense option, a point after which it is highly unlikely that the –Tense option will rise to dominance. Early apprehension of tense is likely to be associated with earlier incorporation of tense into sentence production and subsequent mastery of the system. In other words, apprehension of tense is a necessary but not sufficient condition for producing an adultlike sentence frame. In the GML account, the realization of surface forms through grammatical encoding demands learning the specific surface forms as well as automatization of tense inflection in sentence production (Blom & Wijnen, 2006; Rispoli, 2003; Rispoli & Hadley, in press; Rispoli et al., 2008, 2009). As such, GML predicts a delay between apprehension and the realization of tense morphemes in sentence production, providing an alternative explanation for children's use of unmarked verb forms in their early sentences. At the same time, GML predicts developmental continuity between apprehension and the gradual incorporation of tense morphemes in increasingly diverse syntactic contexts.

Future Directions and Clinical Applications

It is our hope that the design features of this study will be incorporated into future investigations exploring relationships between parent input and children's grammatical development. In particular, we used growth-relevant dependent variables to characterize morphosyntactic growth over time (cf. Richards, 1994; Snow, 1994). This allowed us to investigate variables that predicted developmental growth rates, not static measures at a single point in time. We also examined the relative contribution of parent input together with biological and developmental predictors commonly used in risk factor models of specific language impairment (SLI). Our long-term goal is to combine estimates of input informativeness with biological risk factors such as male sex and positive family history of language learning disorders (Hadley & Holt, 2006; Rice, Taylor, & Zubrick, 2008; Zubrick, Taylor, Rice, & Slegers, 2007; Zubrick et al., 2007) to improve the early identification of young children at risk for SLI. Although limited quantity/quality of the language learning environment has been identified as an important variable to consider (cf. Olswang, Rodriquez, & Timler, 1998), there has been little consensus on how to estimate the language learning environment's support for early grammatical acquisition. With this study, we have demonstrated the feasibility of using input informativeness to estimate environmental contributions to children's morphosyntactic growth directly.

Let us be clear about our motivations for this application. Our interest in understanding how input contributes to grammatical growth in typically developing learners is not because we suspect that differences in input are responsible for the late onset of morphosyntactic growth of young children at risk for SLI. Rather, we suspect that in true cases of language impairment, the input is adequate for morphosyntactic learning to take place, but expected growth is not observed. Rice (2003) proposed that affected and unaffected populations differ primarily in the onset of morphosyntactic development, not in the way in which growth proceeds. More recently, Hadley and Holt (2006) provided preliminary findings indicating that children with positive family histories experience later onset and slower growth of tense productivity in comparison with slow typically developing children without such histories, after controlling for gender, language comprehension, and maternal education. Thus, in cases of true impairment, we might expect endogenous biological and/or developmental factors—not environmental ones—to explain more of the variation between affected and unaffected populations. These endogenous differences could reflect maturational readiness for morphosyntactic learning to begin (Wexler, 2003), inherent differences in learning rate (e.g., γ; Yang, 2002), or some other type of developmental readiness. In short, we hypothesize that endogenous factors will explain more of the variation between groups, whereas input properties will explain more of the variation within groups. It is our hope that by exploring the contribution of the language input to early morphosyntactic growth more directly, we will better understand the resilience of children at biological risk with better outcomes and, in turn, be able to design more effective early grammatical interventions.

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Appendix A. Examples of low and high informativeness.

Example of Low Informativeness (4[+T] / 4[+T] + 8[–T] = 0.33 informative)
M now it's [+T] stuck on there.
M is [+T] that enough?
M want [–T] more?
M wanna [–T] put it together?
M you want [–T] help?
M you want [–T] help?
M there you go [–T].
M push [–T] it up the hill.
M push [–T] it up the hill.
M it broke [+T].
M yes, it did [+T] break.
M play [–T] with the cars?

Example of High Informativeness (10[+T] / 10[+T] + 5[–T] = 0.67 informative)
F this is [+T] a tow truck.
F nope, tow truck doesn't [+T] work that well, does [+T] it?
F Elmo is [+T] being towed away.
F put [–T] her in here.
F you press [–T] this button down and it pushes [+T] up.
F let's [–T] see [–T] how this works [+T].
F doesn't [+T] work well.
F daddy's [+T] just not using it correctly.
F you try [–T] it.
F (uh) this is [+T] a ladder of some sort.
F this goes [+T] like this?

Appendix B. Empirical Bayes residuals, growth coefficients, and predicted tense productivity scores for individual child participants.

Child	Linear residual r_1	Quadratic residual r_2	Linear coefficient π_1	Quadratic coefficient π_2	30-month predicted tense productivity
F05	–0.772	.045	–0.191	.114	7.53
F08	–0.009	.046	0.572	.115	14.46
F13	–0.247	.060	0.334	.129	13.47
F16	–0.800	–.004	–0.219	.065	3.27
F17	–0.622	.034	–0.041	.103	7.95
F18	–0.778	.034	–0.197	.103	6.54
F19	–0.100	–.009	0.481	.060	9.19
M01	–0.569	–.018	0.012	.051	4.26
M04	1.217	–.050	1.798	.019	17.75
M06	–0.674	–.016	–0.093	.053	3.45
M08	1.267	–.064	1.848	.005	17.06
M11	–0.126	–.008	0.455	.061	9.06
M13	1.090	–.051	1.671	.018	16.47
M16	0.065	–.081	0.646	–.012	4.83
M17	–0.568	.023	0.013	.092	7.55

Note. The growth coefficients π_1 and π_2 are made up of both fixed and random components, represented in the hierarchical linear modeling person-level model as β and r, respectively (i.e., $\pi_{1i} = \beta_{10} + r_{1i}; \pi_{2i} = \beta_{20} + r_{2i}$). The fixed component reflects the average for the group. The random component r is the residual, or the individual's difference from the fixed component. In Rispoli et al. (2009), the fixed linear and quadratic components, β_{10} and β_{20}, were 0.581 and 0.069, respectively. The predicted tense productivity score at 30 months is computed with the repeated observations model, centered at 21 months, from Rispoli et al. (2009). $Y_{ti} = \pi_{1i}(30 - 21) + \pi_{2i}(30 - 21)^2$.

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