Morphosyntactic Learning and the Development of Tense

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1.   INTRODUCTION

In this article, we propose that the Root Infinitive (RI) phenomenon in child language is best viewed and explained as the interaction between morphological learning and syntactic development. We make the following specific suggestions: The optionality in RI reflects the presence of a grammar such as Chinese which does not manifest tense marking. The gradual elimination of the non-tense-marking grammar is facilitated by the learning of the morphosyntactic system of the target language. Quantitative differences in the input data among morphosyntactic systems result in the cross-linguistic variation in the RI phenomenon. More broadly, we aim to demonstrate that quantitative aspects of language learning data and concrete mechanisms of the language learning process can play an important role in the generative approach to language acquisition.

In Section 2, we give a brief overview of the RI literature along with some methodological remarks regarding the explanation of the phenomenon. In Section 3, we lay out our theory of morphosyntactic learning and the broader variational approach to language acquisition. Our empirical work focuses on the development of tense in Spanish, French, and English. In Section 4 we show through corpus study of child-directed speech that differences in the morphosyntactic systems of these three languages explain the brief RI stage in Spanish acquisition, the prolonged RI stage in English acquisition, as well the intermediate status of the RI stage in French. In Section 5, we discuss how our

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approach relates to various findings established in the previous literature on RI. Section 6 concludes with a general discussion of the proper role of the input data in theories of language acquisition.

2. PRELIMINARY REMARKS

2.1. The RI Phenomenon

One needs no reminder that the problem of Root Infinitive (RI; also known as Optional Infinitive) occupies a central place in language acquisition research. Children learning a typologically diverse range of languages use nonfinite verbs in root clauses, which is not generally grammatical in the corresponding adult languages (Weverink (1989), Platzack (1990), Wexler (1994), Haegeman (1995), Harris and Wexler (1996), Bar-Shalom and Snyder (1997), Schaeffer and Ben Shalom (2004), among others). Some examples are given in (1):

(1) a. Papa have it.   (English)
    b. thee drinken.   (Dutch)
      tea   drink-INF
    c. Dormir   petit bébé.   (French)
      sleep-INF little baby
    d. mein Kakao hinstelln.   (German)
      my   cocoa put-INF
    e. Lashevel al ha-shulxan.   (Hebrew)
      sit-INF   on the-table

While in some of these languages, adults do use RI patterns in certain limited contexts (Rizzi (1994), Wijnen, Kempen, and Gillis (2001), Lasser (2002)), children's use of RI is more robust and is found in wider contexts than adults, indicating that a considerably different grammatical system is at play.[1] The RI phenomenon, therefore, adds to the already impressive range of findings that language acquisition is not simply a matter of children replicating what they hear from adults.

It is important to bear in mind that the RI phenomenon is *gradient*, in two ways. First, there is no evidence that the exit from the RI stage is sudden: rather, the frequency of RI usage drops gradually to adult level, sometimes over the span of 2–3 years or even longer (Behrens (1993), Wijnen and Bol (1993), Haegeman (1995), Phillips (1995)). Second, and cross-linguistically, the distribution of the

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[1]We note, however, that if adult use of root infinitives is significantly higher than zero, this could still be related to extended use of RI in children. We return to this point when we elaborate on our own proposal in Section 4: essentially, adult use of RI would be giving the child conflicting evidence about the obligatoriness of tense marking in her language.

RI is not categorical but rather falls along a continuum. It appears that children learning most morphologically "rich" languages have shorter RI stages and lower frequency of use than those acquiring morphologically simpler languages (Phillips (1995), Wexler (1998), Guasti (2002))—though as we shall see, the notion of "richness" is misleading and needs to be specified more precisely. For example, the production of RI ranges from rare in the Italian acquisition (Guasti (1992)), to a prolonged stage that may extend beyond the third birthday as in the case of Dutch (Haegeman (1995)) and English (Phillips (1995), Harris and Wexler (1996)).

2.2.   Approaches to RI

Here we give a brief summary of some leading proposals in the RI literature. It is impossible in the current context to give a comprehensive survey of the existing theories on the RI phenomenon. Nor will we dwell on the virtues and problems with these proposals (see Phillips (1995), Wexler (1998), Guasti (2002), among others, for reviews). As will become evident later, our own proposal builds on the insights of many of the existing accounts.

   One class of theories locates children's RI behavior in the core syntax, which is conjectured to be qualitatively different from that of an adult speaker of the target language. According to this view, an RI grammar may involve a tense node that is not interpreted at LF (Wexler (1994)), incomplete clausal structures (Rizzi (1994); cf. Radford (1990)), or different checking options in syntactic computation (Schütze and Wexler (1996), Wexler (1998)). Another class of theories relates RI to a combination of syntactic and nonsyntactic factors. For example, it is hypothesized that RI is due to underspecified features in the Tense node, which in turn are connected to the development of pragmatic knowledge (Hoekstra and Hyams (1998)), or to a phonologically null auxiliary that marks tense and represents related semantic properties (Boser, Lust, Santelmann, and Whitman (1992), Whitman (1994)). Still another group of theories links RI to nonsyntactic performance limitations. For instance, Avrutin (1999) suggests that RI results from children's limited resources to carry out utterance planning and other pragmatic computation, while Phillips (1995) attributes RI to the failure of merging the Tense node with the verb, resulting from not-yet-automatic use of morphological knowledge.

   All these accounts have led to important empirical findings in the RI phenomenon, and have advanced our understanding of language acquisition and Universal Grammar in general. However, we believe that a number of crucial problems remain, some of which have not been frequently discussed.

   In our opinion, a theory of RI, in addition to providing an insightful description of the RI stage, must also provide a specific model of how the child exits the RI stage (and why there should be an RI stage to begin with). In other words, what kind of learning *mechanisms* lead the child to abandon an RI grammar,

and on the basis of what kind of learning *data*? Biological maturation, which presumably takes place largely independent of linguistic data, is one possibility (Rizzi (1994), Wexler (1994; 1998)). This proposal is not entirely satisfactory, however, as the mechanisms of biological maturation of linguistic ability are not currently well understood. Moreover, biological maturation abandons the Continuity Hypothesis (Macnamara (1982), Pinker (1984), Crain (1991), Carey (1995), de Villiers (2001)), the hypothesis that children's competence system is not qualitatively different from adults, which has served well in the investigation of child language and cognitive development.

More empirically, it is again useful to bear in the mind the gradient distribution of RI across languages as well as within languages. As noted earlier, the extent of RI use across languages varies quantitatively along a broad spectrum, and for languages with relatively long RI stages, the percentage of RI use declines gradually. Even during the RI stage, it is not the case that the child uses RI exclusively (hence the optionality of RI). These facts seem to indicate that the RI phenomenon cannot be a categorical or universal deficiency in children's grammar. Nor do they support the classic view of grammar development as an on-or-off process of switching parameter values, e.g., triggering (Gibson and Wexler (1994); see Yang (2002)). Finally, it seems unlikely that RI is entirely due to the limitations on processing and other performance sources. For example, there appears to be no independent reason to suppose that Italian children's pragmatic capacity is significantly more advanced than Dutch children's, whereas the former group has at most a very short RI stage and the latter group has a prolonged one. Given the strong correlation between the productivity of RI and the morphological richness of the language (Phillips (1995), Guasti (2002)), it appears that morphological learning must play a crucial—and quantitative—role in the explanation of the RI phenomenon.

Building on these insights from earlier work, we propose an alternative approach to the problem of Root Infinitives, one that is equipped with a concrete model of acquisition in which morphological learning across languages is connected to the underlying grammatical system of RI.

3.   OPTIONALITY, GRAMMAR, AND MORPHOLOGY

3.1.   Variational Learning

We assume the variational learning approach to language acquisition (Yang (1999; 2002; 2004); see Roeper (2000), Kroch (2001), Crain and Pietroski (2002), Rizzi (2005) for similar approaches). Under variational learning, the child's language is modeled as a population of hypotheses whose composition changes during the course of learning. In the present case, this population is an (innate) space of syntactic parameters specified by UG. Each grammar, or

more specifically each parameter, is associated with a probability. It is this probability distribution that changes adaptively in response to the linguistic data in the environment. This differs critically from models such as triggering, where a unique grammar changes into another unique grammar on the basis of linguistic evidence.

Schematically, variational learning proceeds as follows:

(2) For an input sentence s, the child
    a. with probability P_i selects a grammar G_i,
    b. analyzes s with G_i
    c. • if successful, reward G_i by increasing P_i
        • otherwise punish G_i by decreasing P_i

A concrete instantiation, which models the well-known probability matching behavior in the psychology of learning (Bush and Mosteller (1951; 1958), Herrnstein and Loveland (1975); cf. Gallistel (1990)), is as follows:

(3) Given an input sentence s, the learner selects a grammar G_i with probability p_i:

    a. if $G_i \to s$ then $\begin{cases} p_i' = p_i + \gamma(1 - p_i) \\ p_j' = (1 - \gamma)p_j \end{cases}$ if $j \neq i$

    b. if $G_i \not\to s$ then $\begin{cases} p_i' = (1 - \gamma)p_i \\ p_j' = \dfrac{\gamma}{N - 1} + (1 - \gamma)p_j \end{cases}$ if $j \neq i$

In this model, known as *Linear Reward Penalty*, a parameter γ controls the rate of learning, i.e., how much reward/punishment a grammar receives based on its success/failure in analyzing the input data on an item-by-item basis. We direct the reader to Yang (2002) for the formal properties of the variational model and in particular its application to a parametric space, while restricting ourselves to some general remarks here.

The basic learnability result is straightforward. Clearly, the target grammar, by being consistent with the input data, will never be directly punished. All other grammars in the UG space, however, are at least inconsistent with some portion of the input data. Thus, nontarget grammars will necessarily be driven to extinction by the target grammar, ensuring convergence. As a concrete example, consider the parameter of verb raising to tense. In the variational model, the learner initially has probabilistic access to both the $+$ and the $-$ value of the parameter. In a French-speaking environment, however, the $-$ value will be punished. This is not to say that it will be punished all the time. For instance, a sentence such as "Jean voit Marie" obviously is consistent with both values

of the parameter: in other words, the child learner will succeed regardless of whether she has selected the $+$ or $-$ value to analyze this sentence. When positional markers are present, however, as in the case of

(4) Jean voit souvent Marie.
    Jean sees often   Marie.
    'Jean often sees Marie.'

where the adverb follows the tensed verb, only the $+$ value will succeed in analyzing the sentence. Hence, if the learner has probabilistically selected the $+$ value for syntactic analysis, it will result in an increment of the probability associated with $+$. On the other hand, if the $-$ value is selected, its failure in analyzing the sentence decreases its associated probability, and thus indirectly increasing that of the $+$ value. It is clear that the $+$ value, the target, will eventually eliminate the $-$ competitor.

The probabilistic nature of the variational model has a number of features that distinguish it from the traditional conception of parameter setting. First, unlike the traditional models of learning such as triggering, even unambiguous evidence such as (4) does not settle learning decisively but only nudges the learner toward the target value. The rise of the target grammar is gradual, as its probability gradually approaches 1; this appears to be characteristic of language development in general. Second, the demise of nontarget grammars is also gradual. In other words, nontarget grammars may linger around for extended periods of time, albeit accessed with decreasing probabilities as they are gradually driven out by the target grammar. This leads to a principled interpretation of "errors" in child language as potential adult grammars sanctioned by UG, thus bringing the variational model in line with the guiding principle of the Continuity Hypothesis.

Finally, and more pertinent to the present article, the variational model makes it possible to integrate the theory of parameters into a quantitative model of language learning, as competing grammars may be associated with quantitative fitness values. A useful measure is the probability that a grammar is penalized in a specific linguistic environment, i.e., the percentage of sentences in the input that the grammar is inconsistent with. Adapting the formulation of Bush and Mosteller (1958), we have:

(5) The *penalty probability* of grammar G_i in a linguistic environment E is:[2]

$$c_i = \Pr(G_i \nrightarrow s \mid s \in E)$$

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[2] We write $s \in E$ to indicate that s is an utterance in the environment E, and $G \rightarrow s$ to mean that G can successfully analyze s. Formally, the success of $G \rightarrow s$ can be defined in any suitable way, possibly even including extra-grammatical factors; a narrow definition that we have been using is simply parsability.

Ceteris paribus, the speed with which a grammar (or a parameter value) rises to dominance is correlated with its competitor's penalty probability. More formally, consider two grammars, target G_1 and the competitor G_2, with $c_1 = 0$ and $c_2 > 0$. At any time, $p_1 + p_2 = 1$. With the presentation of each input sentence, the expected increase of p_1, $E[\Delta p_1]$, can be computed as follows:

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\begin{aligned}
(6) \quad E[\Delta p_1] &= p_1 \gamma (1 - p_1) && \text{with Pr.} p_1, \ G_1 \text{ is chosen and } G_1 \rightarrow s \\
&+ p_2 (1 - c_2)(-\gamma) p_1 && \text{with Pr.} p_2 (1 - c_2), \ G_2 \text{ is chosen and} \\
& && \qquad G_2 \rightarrow s \\
&+ p_2 c_2 \gamma (1 - p_1) && \text{with Pr.} p_2 c_2, \ G_2 \text{ is chosen but } G_2 \nrightarrow s \\
&= c_2 \gamma (1 - p_1)
\end{aligned}
$$

that is, the increase of the probability of the target grammar (p_1) is correlated with the penalty probability of the competitor (c_2), which can be directly estimated from corpus studies of child directed speech. Note, however, that these fitness measures are not statistics that the child learner needs to explicitly keep track or make use of: this point has often been misunderstood (e.g., Westergaard (2006)). This, then, allows one to make quantitative comparisons for the development of different aspects of syntactic development (Legate and Yang (2002), Yang (2004)).

3.2.   Optionality as Probabilistic Grammar

These unique features of the variational model suggest an alternative approach to the RI phenomenon. Previous theories, which include both generative accounts as well as empiricist learning accounts (e.g., Pine, Rowland, Lieven, and Theakston (2005)), have largely focused on the deviation of the RI grammar from the *target* grammar that the child eventually acquires. The variational framework, by contrast, seeks parallels between how the RI grammar deviates from the target grammar, and how the RI grammar relates to the totality of grammatical options made available by UG. It is therefore useful to turn to the typology of languages in search of possible competing grammars that may form the basis of optionality in the RI phenomenon. In all RI languages, tense is an active morphosyntactic feature of the grammar: call these [+Tense] languages. However, in many other languages—call these [−Tense] languages—tense is not expressed morphosyntactically. A few examples from Mandarin Chinese are given below. Although Mandarin Chinese lacks tense, the semantics of temporal distinctions may still be expressed in the language through adverbial adjuncts as in (7a) (see Enç (1987) and Smith (1991) for a discussion related to the semantic encoding of temporal relations in [−Tense] languages). Aspect morphology may also be present (7b):

(7) a. Zhangsan tiantian   da   qiu.
       Zhangsan everyday play ball.
       'Zhangsan plays ball everyday.'
    b. Zhangsan zai   da   qiu.
       Zhangsan ASP play ball.
       'Zhangsan is playing ball.'

Important for the present discussion is that since UG makes [−Tense] grammars an available option (i.e., Mandarin Chinese is a human language), a child acquiring a [+Tense] language must rule out this option.[3] Under the variational approach of probabilistic learning, the [−Tense] option may take nonzero time to be eliminated, and its elimination is based on the input data in the linguistic environment of [+Tense] languages. If so, the use of nonfinite verbs in root clauses of [+Tense] languages is expected, and expected to be optional, as the [−Tense] option is accessed with a decreasing probability.[4] When the [−Tense] option is accessed, children will use verb forms that do not mark tense, i.e., infinitives. Thus, the differences between an RI-stage grammar and the full specification of UG are only quantitative, rather than qualitative, contrary to the biological maturation accounts.

3.3. Morphological Evidence for Syntax

On what basis does the child (gradually) eliminate the [−Tense] grammar in favor of the [+Tense] grammar? Most obviously, clauses with overt tense morphology, like English -*ed*, will reward the [+Tense] grammar and punish the [−Tense] grammar. However, the issue is more complex in two respects.

First, certain morphemes that do not express tense directly may nevertheless serve as evidence for the [+Tense] grammar. Consider English -*s*, which marks third singular, but only in the present tense. It is well established that children have determined the correct features realized by tense/agreement morphology well before they use them consistently; for example, Behrens (1993), Guasti (1992), Torres (1995) demonstrate that children's morphological errors are errors of omission, rather than use in inappropriate morphosyntactic contexts. In addition, there is evidence that English children can correctly identify English 3Sg -*s* as expressing 3Sg in the environment of present tense. For instance, Harris and Wexler (1996) show that even though English children do not use

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[3]And thus we forgo a detailed discussion on the proper, but largely orthogonal, theoretical treatment of these languages, e.g., whether [−Tense] languages have identical clausal structure and functional nodes as [+Tense] languages.

[4]So far as we know, Weinberg (1994), in a commentary on Wexler (1994), was the only other researcher that suggested identifying the use of RI with a grammar like Chinese, although this proposal was not developed further by Weinberg.

-*s* consistently in third person singular present tense, they almost never use it in incorrect person/number combinations. Thus, tokens of 3Sg -*s*, although not expressing tense, do require tense for their realization for what is known as secondary exponence in morphology. Therefore, these forms also reward the [+Tense] grammar and punish the [−Tense] grammar. When determining the frequency of relevant input to the child in any particular language, morphology that requires tense must be included (for related discussion, see Carstairs (1987) on primary versus secondary exponence, and Harley and Noyer (1999) on primary versus secondary expression of a feature).

Second, consider the impact of verb forms that are not overtly marked for tense, nor morphologically dependent on tense. In order for these forms to be compatible with a [+Tense] grammar, the learner must make the additional postulation of zero tense morphology.[5] However, they are also compatible with a [−Tense] grammar: more straightforwardly so, in fact, for the [+Tense] option requires the postulation of zero morphology which may be disfavored for learnability reasons. If the child's language acquisition device attempts to analyze the form with a [−Tense] grammar, the analysis will be successful and the form will (ultimately incorrectly) punish the [+Tense] grammar, and reward the [−Tense] grammar. Eventually, the evidence for the [+Tense] grammar must overwhelm this apparent evidence for the [−Tense] grammar, and zero tense morphology will be consistently posited. However, until that point, the verb forms that exhibit no tense or tense-dependent morphology are liable to punish the target [+Tense] grammar. We should add that for languages in which adults do produce a nontrivial number of RIs (Rizzi (1994), Lasser (2002))—Dutch, for example, (Wijnen et al. (2001))—the rise of the [+Tense] option may be further delayed, for the child is bombarded with inconsistent data.

Note that in the present discussion, we have avoided the informal notion of a "rich" or "poor" morphology that has played a significant role in previous theories that have tried to address the cross-linguistic distribution of RI in acquisition. For us, the role of morphology in the rise of the [+Tense] grammar is a very specific one, i.e., that the tense feature is expressed, by either primary or secondary exponence. One can imagine a "poor" morphology devoid of number, gender, or person marking but with consistent tense marking; under our account, the [+Tense] grammar would rise to dominance quickly. Indeed, Japanese verbs do not have agreement morphology,[6] but consistently mark Tense; notably, Japanese is not an RI language (Sano and Hyams (1994),

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[5]The willingness to accept zero morphemes depends on one's theoretical persuasions; see, e.g., Anderson (1992) for a different view.

[6]Honorific markers have been considered a limited case of agreement (Harada (1976), Shibatani (1977), Boeckx and Niinuma (2004); see Bobaljik and Yatsushiro (2006) for an opposing view), but these do not appear on tensed verbs and thus would not provide evidence for a [+Tense] grammar.

Sano (1999)).[7] For us, then, it is important to quantify the amount of morphological evidence that could drive the learner along [±Tense] one way or another: this needs to be done on a case-by-case basis, with a detailed analysis of the specific morphological system, and cannot be achieved by appealing to the informal notions "rich" and "poor." We turn to this question in Section 4.

4. QUANTITATIVE EVIDENCE FOR TENSE ACROSS LANGUAGES

Under our proposal, the evidence for the grammatical option of [±Tense] is manifested in the verbal morphology of the language. Since the features active in the morphosyntax of a language are language-specific, they must be learned. Learning requires data, which in turn takes time to accumulate. On our view, this is where languages diverge with respect to RI: it is our contention that the morphological evidence for [+Tense] in languages with shorter RI stages is far more abundant than the morphological evidence in languages with extended RI use.

In this section, we quantify our claim with an analysis of the inflectional paradigms of three languages sampled from the RI spectrum—specifically, Spanish, French, and English—and situate the learning of the morphological systems of these languages in a broad context of morphosyntactic acquisition. It must be noted that the use of root infinitives, just like many other aspects of grammatical development, shows considerable individual variation. Thus, cross-linguistic generalizations of root infinitive use reflect tendencies rather than absolutes. And it is for this reason that we chose three languages for which children's quantitative uses of root infinitives are significantly different, and these differences have been consistently found in the research literature. Spanish is a language where children have relatively infrequent use of root infinitives. For example, Grinstead (1994) found that prior to 2;0, about 10% of otherwise finite verbs are infinitives, and by 2:6, this figure drops below 5%. English, by contrast, has a much prolonged RI stage. As noted by Phillips (1995) (see also Hoekstra and Hyams (1998)), Adam's use of infinitives was still extensive at 3;0. Even the linguistically precocious Eve managed to produce approximately 50% root infinitives by the time her recording sessions stopped at 2;3. In the acquisition of French, the frequency of root infinitives is found to be at 15–30% for three children in the age group of approximately 1;8–2;6 (Rasetti (2003)), while Pierce's (1992) study of the same children reported somewhat higher frequencies.

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[7]An interesting case would be a language that has rich agreement morphology yet little tense marking. Unfortunately, we are not aware of an empirical study on the acquisition of such a language.

We show that the disparities across these three languages can be attributed to their verbal morphologies, which lead to the rapid decline of the [−Tense] grammar in Spanish, and a more gradual decrease in English, with French situated between these two extremes.

4.1. Morphological Evidence for Tense in Spanish

In order to estimate the amount of crucial data available to the Spanish child, we counted the frequency of tensed verb forms in child-directed Spanish. Of these forms, we counted how many express neither tense morphology, nor tense-dependent morphology (see discussion of primary and secondary expression of features in Section 3.2 above), and thus are liable to incorrectly punish the [+Tense] grammar. Forms of the verb in Spanish that are overtly marked for tense and so were counted as correctly rewarding the [+Tense] grammar are the future, conditional, and imperfective.

(8) a. Future 3Sg *cantar* 'to sing'
        cantará
    b. Conditional
        cantaría
    c. Imperfective past
        cantaba

In contrast, the present tense of verbs in Spanish does not exhibit an overt tense morpheme; thus, any verbs in the present tense without tense-based agreement or other tense-based morphology would fall into this category of incorrectly punishing [+Tense]. All person/number combinations, excepting the third singular discussed immediately below, exhibit agreement suffixes that do not appear on untensed verb forms—infinitivals and participles (the latter expressing aspect rather than tense). Therefore, these all correctly reward the [+Tense] grammar.

(9) a. Present *cantar* 'to sing'
        1Sg   canto
        2Sg   cantas
        3Sg   canta
        1Pl   cantamos
        2Pl   cantáis
        3Pl   cantan
    b. cf. Infinitive
        cantar
    c. cf. Past Participle
        cantado
    d. cf. Present Participle
        cantando

The subjunctive uses the theme vowel *e* throughout, which is not found on [−Tense] forms of *ar* verbs, and thus was counted as rewarding the [+Tense] grammar.

(10) Subjunctive

1Sg	cante
2Sg	cantes
3Sg	cante
1Pl	cantemos
2Pl	cantéis
3Pl	canten

Finally, the perfective past exhibits tense-dependent morphology in all person-number combinations, and so was counted as rewarding the [+Tense] grammar:

(11) Perfective past

1Sg	canté
2Sg	cantaste
3Sg	cantó
1Pl	cantamos
2Pl	cantasteis
3Pl	cantaron

Consider now the third singular form of the present: *canta* 'sings.' This form exhibits only the suffixal *a* theme vowel of *ar* verbs. Whether such forms reward or punish [+Tense] is dependent on the analysis of the theme vowel.[8] Recent theoretical work on theme vowels in Spanish, Oltra-Massuet and Arregi (2005), argues that all theme vowels are dependent on tense (and agreement) in Spanish. Thus, third singular present forms will also reward [+Tense] in Spanish. This leads to an overwhelming preponderance of evidence for the [+Tense] grammar in Spanish, leaving only irregular imperatives that consist only of the bare stem, and any adult root infinitives, as potentially punishing [+Tense].

(12) Examples of bare stem imperatives

pon	poner	'to put'
sal	salir	'to leave'
ten	tener	'to have'
ven	venir	'to come'

Although we find Oltra-Massuet and Arregi's work convincing, it is notable that the theme vowel for *-ar* verbs[9] is *a* in almost all of the [+Tense] forms of

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[8]We thank an anonymous reviewer for encouraging us to consider the issue of the theme vowel more closely.

[9]The highest theme vowel in Oltra-Massuet and Arregi's (2005) system.

the *-ar* verbs, including the third singular, and is *a* in all three of the nonfinite forms. Thus we made the most conservative choice and counted the third singular present forms of *-ar* verbs as potentially punishing the [+Tense] grammar, while admitting that we may be underestimating the amount of evidence for the [+Tense] grammar available to the Spanish child. Regular imperative forms are identical to the third singular present and were treated identically.

(13) Imperative
     canta

The theme vowels for *-er* and *-ir* verbs do not exhibit the same consistency regardless of tense that is found in *-ar* verbs. Thus, we treated them as dependent on [+Tense], consistent with Oltra-Massuet and Arregi's analysis, and counted them as rewarding the [+Tense] grammar.

(14) a. Present *vivir* 'to live'
        1Sg   vivo
        2Sg   vives
        3Sg   vive
        1Pl   vivimos
        2Pl   vivís
        3Pl   viven
     b. cf. Infinitive
        vivir
     c. cf. Past Participle
        vivido
     d. cf. Present Participle
        viviendo

(15) a. Present *comer* 'to eat'
        1Sg   como
        2Sg   comes
        3Sg   come
        1Pl   comemos
        2Pl   coméis
        3Pl   comen
     b. cf. Infinitive
        comer
     c. cf. Past Participle
        comido
     d. cf. Present Participle
        comiendo

All other forms of *-er* and *-ir* verbs exhibit tense morphology or tense-based morphology and so reward the [+Tense] grammar.

(16) a. Future 3Sg *vivir* 'to live'
      vivirá
   b. Conditional
      viviría
   c. Imperfective past
      vivía
   d. Imperative
      vive

(17) a. Subjunctive *vivir* 'to live'
      1Sg   viva
      2Sg   vivas
      3Sg   viva
      1Pl   vivamos
      2Pl   viváis
      3Pl   vivan
   b. Perfective past
      1Sg   viví
      2Sg   viviste
      3Sg   vivió
      1Pl   vivimos
      2Pl   vivisteis
      3Pl   vivieron

(18) a. Future 3Sg *comer* 'to eat'
      comerá
   b. Conditional
      comería
   c. Imperfective past
      comía
   d. Imperative
      come

(19) a. Subjunctive *comer* 'to eat'
      1Sg   coma
      2Sg   comas
      3Sg   coma
      1Pl   comamos
      2Pl   comáis
      3Pl   coman

    b. Perfective past
       1Sg   comí
       2Sg   comiste
       3Sg   comió
       1Pl   comimos
       2Pl   comisteis
       3Pl   comieron

Finally, several classes of Spanish verbs require a stem change in the singular and in the third plural of the present tense.[10] An example follows:

(20) a. Stem change in present tense: *poder* 'be able to'
       1Sg   puedo
       2Sg   puedes
       3Sg   puede
       1Pl   podemos
       2Pl   podéis
       3Pl   pueden
    b. cf. Infinitive
       poder
    c. cf. Past Participle
       podido
    d. cf. Present Participle
       podiendo
    e. Imperative
       puede

This stem change again requires tense for its application, and thus correctly rewards the [+Tense] grammar. The third singular present and second singular imperative forms of such verbs thus were not counted as punishing the [+Tense] grammar.

These counting criteria for Spanish are summarized in Table 1. We examined the child-directed utterances from 14 files in the Fernández and Aguado corpus in the CHILDES database (MacWhinney (1995)). The counts were carried out by hand. Table 2 reports our findings.

There are $1782/2226 = 80.1\%$ of input tensed verbs with verbal morphology that unambiguously implicate the [+Tense] grammar. These are countered by only $444/2226 = 19.9\%$ of input tensed verbs that, by virtue of being consistent with the [−Tense] grammar, may impede the gradual dominance of the [+Tense] grammar. The [+Tense] grammar has a significant numerical advantage: 60.2%.

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[10]This stem change is also found in the present subjunctive and the imperative, both of which arguably involve (present) tense.

TABLE 1
Types of Morphological Evidence in Spanish for Acquisition of [± Tense]

		Rewards [−Tense] Grammar	*Rewards [+Tense] Grammar*
-ar		3Sg present	All other present tense forms
		Imperative	Future, conditional, imperfective past
			Perfective past, subjunctive
-ir, -er			Present
			Imperative, future, conditional, imperative past
Irregular			Stem change
Irregular		2Sg bare stem imperatives	
		Adult use of root nonfinite verbs	

The morphology of Spanish, then, offers the child ample opportunity to learn that their language makes use of tense.

If our approach to RI is on the right track, then the cross-linguistic distribution of RI is due to the (gradient) quantities in the morphological evidence for the [+Tense] grammar. We would therefore expect that the extended RI languages have a smaller amount of evidence for the marking of Tense than a brief RI language such as Spanish. To this end, we turn to a corpus study of child-directed English.

4.2. Morphological Evidence for Tense in English

In order to estimate the amount of crucial data available to the English child, we counted the frequency of verb forms that express tense, or require tense for their usage, that are present in adult speech in English CHILDES. (Again, see the previous discussion of primary and secondary expression of features.)

In English, past tense is overtly marked for most regular and irregular verbs, for example, *jump-ed* and *burn-t*; all such tokens were counted as evidence for [+Tense]. In addition, a class of irregular verbs with no tense suffix exhibit stem allomorphy dependent on the past tense, for example, *sang*. These were counted as well. In the present, third person singular shows the tense-dependent

TABLE 2
Quantitative Evidence of Verbal
Inflection in Child-Directed Spanish
for Acquisition of [±Tense]

Rewards [+Tense]	1782/2226
Rewards [−Tense]	444/2226
([+Tense]-[−Tense])%	60.2%

TABLE 3
Types of Morphological Evidence in English for Acquisition of [± Tense]

	Rewards [−Tense] Grammar	Rewards [+Tense] Grammar
Past tense	No change irregulars	All the rest
Present tense modal	All	
Present tense verbs	All the rest	Third person singular
Present tense auxiliary		All
Bare stem verbs	All	

-s; such tokens reward the [+Tense] grammar. In addition, the auxiliary *be* in the present tense (i.e., *am*, *are*, *is*), including the contracted forms (which are abundant in child-directed speech), shows agreement in the present tense, and therefore counts as secondary exponence evidence for the [+Tense] grammar.

On the other side of grammar learning, forms in English exhibiting zero expression of tense and no tense-dependent morphology were counted as potential evidence against the [+Tense] grammar. In English these include, obviously, the non-third singular forms of regular verbs in the present tense. Likewise, modals in the present tense, which do not mark for agreement at all, are included as well. In addition, utterances that contain only a bare verb such as "play checkers?" and "leave them in there," which are indistinguishable from a Chinese-like [−Tense] grammar, are also included. Finally, a small class of verbs that do not change in past tense, for example, *hit-hit*, also punish the [+Tense] grammar; these verbs are tallied as well. All the verbal forms that we have counted are summarized in Table 3. We took a random sample of 58,447 child-directed sentences from Brown's (1973) Harvard studies. Because English morphology is relatively simple, and the distributional cues for morphological analysis are relatively clear, there are industrial strength, part-of-speech tagging tools that are sufficiently accurate and informative, thereby making large-scale corpus analysis possible. For the present study, we used the part-of-speech tagger of Brill (1995), which achieves an accuracy of 95–97% on unrestricted English texts: this level of performance is acceptable for our purposes.[11] The results of our counts are summarized in Table 4. The input analysis of English morphology reveals that there is in fact relatively little unambiguous evidence for the [+Tense] option in the grammar. Though [+Tense] still possesses the numerical advantage—a net difference of 5.8%—it is far less robust than in the case of Spanish (60.2%).

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[11]For instance, the tagger can correctly distinguish infinitives ('to run') from nonthird person singular present tense ('I run'). We have noted, however, that for technical reasons that needn't concern us here, the tagger often mis-tags words immediately preceding the contracted negation marker ("n't"). These were manually corrected.

TABLE 4
Quantitative Evidence of Verbal Inflection in
Child-Directed English for [±Tense] Acquisition

Rewards [+Tense]	37090/70047
Rewards [−Tense]	32857/70047
([+Tense]-[−Tense])%	$(52.9 - 47.1) = 5.8\%$

4.3. Morphological Evidence for Tense in French

Finally, we considered the evidence available to the French child regarding the status of the [+Tense] grammar in her language. The future and conditional show overt tense marking and so correctly reward the [+Tense] grammar. The imperfective past also correctly rewards the [+Tense] grammar through tense-dependent agreement morphology:

  (21) a. Future 3Sg *chanter* 'to sing'
            chantera
        b. Conditional
            chanterait
        c. Imperfective past
            chantait

Similarly to Spanish, French does not exhibit overt tense marking in the present or the imperative. The agreement morphology found in French is significantly more impoverished as compared to Spanish. An *-er* verb paradigm follows; in contrast to Spanish, the only pronounced suffixes are those in the first plural and second plural; other forms are pronounced as bare stems. The second plural suffix is identical to the infinitive and past participle, leaving the first plural as the only tense-dependent agreement morphology.

  (22) a. Present *chanter* 'to sing'
            1Sg   chante
            2Sg   chantes
            3Sg   chante
            1Pl   chantons
            2Pl   chantez
            3Pl   chantent
        b. cf. Infinitive
            chanter
        c. cf. Past Participle
            chanté

d. cf. Present Participle
chantant
e. Imperative
chante

In the *-re* verb paradigm, the first and second plural exhibit tense-dependent morphology.

(23) a. Present *vendre* 'to sell'
1Sg   vends
2Sg   vends
3Sg   vend
1Pl   vendons
2Pl   vendez
3Pl   vendent
b. cf. Infinitive
vendre
c. cf. Past Participle
vendu
d. cf. Present Participle
vendant
e. Imperative
vends

In the *-ir* verb paradigm, all singular present forms exhibit only the /i/ suffix found on the past participle. The third plural form exhibits only the /is/ suffix found in the present participle. Thus, again only first and second person plural exhibit tense-based agreement morphology.[12]

(24) a. Present *grandir* 'to grow'
1Sg   grandis
2Sg   grandis
3Sg   grandit
1Pl   grandissons
2Pl   grandissez
3Pl   grandissent
b. cf. Infinitive
grandir

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[12]The /i/ suffix may be comparable to the Spanish /a/ theme vowel, both found in most [+Tense] and all [−Tense] forms of the verb.

    c. cf. Past Participle
       grandi
    d. cf. Present Participle
       grandissant
    e. Imperative
       grandis

Thus, more present verb forms in French than in Spanish fail to provide unambiguous evidence for the [+Tense] grammar. This is all the more true in that the first plural and second plural are infrequently used in spoken French: such forms were rare, but present, in our data.

Like Spanish, many French verb forms exhibit tense-based stem change in the present. These, despite the lack of overt agreement or tense morphology, do provide evidence for the [+Tense] grammar. An example follows.

(25) a. Present *tenir* 'to hold'

1Sg	tiens
2Sg	tiens
3Sg	tient
1Pl	tenons
2Pl	tenez
3Pl	tiennent

    b. cf. Infinitive
       tenir
    c. cf. Past Participle
       tenu
    d. cf. Present Participle
       tenant
    e. Imperative
       tiens

Such verbs found in the selection included *tenir*, *re*(*venir*), *savoir*, *pouvoir*, *vouloir*, *falloir*, *devoir*, *sortir*. In addition, the verbs *aller*, *avoir*, and *être* (excepting the second plural) show significant stem allomorphy in the present, and thus also provide evidence for the [+Tense] grammar:

(26) a. Present *aller* 'to go'

1Sg	vais
2Sg	vas
3Sg	va
1Pl	allons
2Pl	allez
3Pl	vont

b. Present *être* 'to be'
   1Sg   suis
   2Sg   es
   3Sg   est
   1Pl   sommes
   2Pl   êtes
   3Pl   sont

c. Present *avoir* 'to have'
   1Sg   ai
   2Sg   as
   3Sg   a
   1Pl   avons
   2Pl   avez
   3Pl   ont

This counting procedure for French is summarized in Table 5.

We examined child-directed utterances from the Leveille corpus (Philippe) and the Geneva corpus (Marie) in the CHILDES database. The counts were carried out by hand. Table 6 reports our findings. There are $1558/2231 = 69.8\%$ of input tensed verbs with verbal morphology that unambiguously implicate the [+Tense] grammar. These are countered by $673/2231 = 30.2\%$ of input tensed verbs that, by virtue of being consistent with the [−Tense] grammar, may impede the gradual dominance of the [+Tense] grammar. The numerical advantage of the [+Tense] grammar in French is thus 39.6%. The morphology of French, then, provides far more opportunity for the child to learn that the tense is an active morphosyntactic feature in their language than English, but not as much as Spanish. The status of the French RI stage as intermediate between English and Spanish, but closer to Spanish, is thus directly explained by our model. The results from the corpus study are summarized in Table 7.

TABLE 5
Types of Morphological Evidence in French for Acquisition of [± Tense]

	Rewards [−Tense] Grammar	*Rewards [+Tense] Grammar*
-er	All other present forms	1Pl present
		Future, conditional, imperfective past
		Subjunctive, imperative
-re, -ir	All other present forms	1Pl present, 2Pl present
		Future, conditional, imperfective past
		Subjunctive, imperative
Irregular		Stem change
	Adult use of root nonfinite verbs	

TABLE 6
Quantitative Evidence of Verbal
Inflection in Child-Directed French
for Acquisition of [±Tense]

Rewards [+Tense]	1558/2231
Rewards [−Tense]	673/2231
([+Tense]-[−Tense])%	39.6%

5.   MORPHOLOGY LEARNING AND SYNTACTIC DEVELOPMENT

Our proposal in this article constitutes a learning-theoretic model that retains many insights of the previous analyses of the RI phenomenon. We agree with all (generative) accounts that RI is a genuine grammatical phenomenon rooted in UG and by virtue of its derivation from the target grammar along with the associated grammatical properties, constitutes a forceful argument against the empiricist position to language acquisition. We agree with Schütze and Wexler (1996) and Wexler (1998) that there is a connection between tense and agreement marking in both child and adult grammars, and in particular, that tense and agreement may be separately licensed. We agree with Hoekstra and Hyams (1998) and Schaeffer and Ben Shalom (2004) in recognizing that morphology plays an important and revealing role in the underlying grammatical system of Tense. In addition, for Boser et al. (1992) and Whitman (1994), RI results from a null auxiliary whose function is, among others, to spell out the tense feature; for us, it results from the presence of a [−Tense] grammar, which eliminates the need to spell out the tense feature.

Perhaps our account is closest to that of Phillips (1995), which also relates morphological learning to RI in a quantitative way. In Phillips' account, the underlying grammar system during the RI stage is much like the target adult grammar and the performance of the child's morphological system—specifically,

TABLE 7
Quantitative Comparisons of the Amount of Morphological
Evidence in Favor of the [+Tense] Grammar and the
Reported Duration of the RI Stage in Three Languages

Language	% for [+T]-% for [−T]	Duration of RI
Spanish	60.2%	∼2;0
French	39.6%	∼2;8
English	5.8%	>3;5

the realization of inflectional features—is directly responsible for the use of RI. In our account, the underlying RI grammar system is a statistical ensemble of potential adult-like grammars (including but not limited to the target grammar), and that is because the morphological system, whose development is frequency sensitive, has not yet driven out the [−Tense] option.

By providing a unified framework in which the interaction of morphology and grammar learning can be addressed, our model complements previous models in the RI literature. Space prohibits us from providing a thorough survey; below we discuss two results that have received considerable attention in the literature.

Upon close scrutiny, not all findings reported in the literature can be maintained. For instance, an oft-cited generalization concerns the clustering of null subjects and nonfinite verbs on the one hand, and that of overt subjects and finite verbs on the other. Unfortunately, this generalization does not hold up cross-linguistically, as noted by Phillips (1995), among others. In addition, there are distributional generalizations in children's null subjects that pattern with a topic-drop grammar rather than the tense of the verb (Yang (2002)). Finally, the developmental time courses of null subjects and RI simply do not match. For instance, Figure 1 reproduces the longitudinal developments of null subjects and RI of a Dutch child (the Hein corpus; Haegeman (1995)): Note that his RI stage essentially ended at 3;0–3;1, when his usage dropped to around 5%, yet there were still about 30% of null subject sentences in his production.
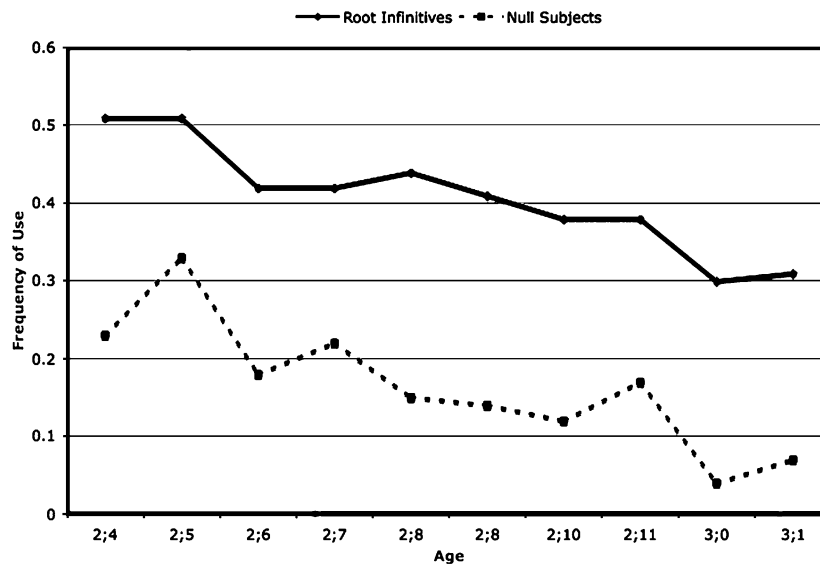

FIGURE 1   The longitudinal development of null subjects and RI; data from Haegeman (1995).

Consider next, another prominent finding in the RI research, which concerns the relation between the form of verbs and the syntactic positions they occupy. Since Weverink (1989) and Pierce (1992), it has been known and since robustly confirmed (see Wexler (1994) for a summary) that verbs raising to a high position (e.g., T) in the matrix clause—as indicated by positional markers such as negation or adverb—are almost always finite, whereas the verbs that remain in-situ—also indicated by negation and adverb—are almost always nonfinite. And this is apparently so even for children barely in the multi-word stage of syntactic acquisition. The following findings from Deprez and Pierce (1993) are typical:

(27) a. marche pas   (finite & high)
        works   not
     b. elle   a   pas   la bouche   (finite & high)
        she   has not   the mouth
     c. pas   la poupée   dormir   (nonfinite & low)
        not   the doll   sleep
     d. pas   chercher   les voitures   (nonfinite & low)
        not   look.for   the cars

Under our framework, a straightforward way to account for this pattern is to assume that, as a matter of UG principle, [+Tense] grammar is a necessary—though not sufficient—condition for raising the verb. This can be viewed as building on the insight of Pollock (1989) through (early) minimalism that one of the means of spelling out the Tense features—in, by definition, a [+Tense] grammar—is to move the verb to T, whereas another option is to lower T to the verb, as in the case of English. Though we are not aware of any counterexample to this position, it would nevertheless commit us to the position that verbs do not undergo movement to Tense or similar functional nodes in [−Tense] grammars such as Chinese—which at least one of us is not comfortable with.

Another way of accounting for the data in (27) more closely follows the spirit of probabilistic and quantitative learning advanced in the present article. The observed fact means that children at a fairly young age have learned, as a fact about their specific languages, that Tense is far more likely to be inflected when the verb is high—as indicated by its position relative to negative and VP-level adverbs—than otherwise, and indeed, they very quickly learn that the probability of the former is close to 1. This notion can be captured in terms of conditional probabilities:

(28) $P([+\text{Tense}]|\text{Verb high}) \approx 1 \gg P([+\text{Tense}])$.

Thus, we again quantitatively measured the amount of evidence that is used to learn these probabilities. Here we considered the child-directed speech in the

TABLE 8
Verb Form and Position in Child-Directed French

Verb Position	Rewards [+Tense]	Rewards [−Tense]
High	138 (90.2%)	15 (9.8%)
Ambiguous	687 (66.8%)	342 (33.2%)

files of one of the two French children examined in Section 4.3, as the statistical evidence for tense for them is virtually the same. To this end, we have separated verbs into two classes, focusing specifically on those that are unambiguously high. For those, we expect the evidence for the [+Tense] option is far more abundant than verbs that are not unambiguously high. To gather these statistics, we consider two cases for which the verb is unambiguously high:

(29) a. verbs that precede negation or adverb, such as (4)
    b. verbs that precede the subject, such as the phrase commonly used to introduce a question in French *est-ce que* ('is it that'), where the verb has raised to C—and thus at least to T.[13]

Of course, verbs that are unambiguously high may be morphologically ambiguous for the [±Tense] option. After all, some verbs have null tense morphemes that render them indistinguishable from nonfinite ones; see the discussion of the French verbal paradigm and its relation to tense marking in Section 4.3. However, the numerical advantage of unambiguously [+Tense] verbs in high positions is compelling (thanks largely to morphologically finite auxiliaries). Our results are summarized in Table 8.

Indeed, when the verb is high, it overwhelmingly rewards the [+Tense] grammar. The advantage for [+Tense] when conditioned upon a high verb position is almost 80%, which is even considerably higher than that in Spanish (60.1%; see Section 4.1). Given the fact that the Spanish RI stage is very short if existent at all, we have every reason to expect that the [+Tense] option can be determined reliably by French children when the verb is in high clausal positions.[14]

[13]It has been argued that some post-verbal subjects in child French are VP-internal (Deprez and Pierce (1993)), but this position has been convincingly disconfirmed with much larger corpus work (Stromswold and Zimmerman (1999)): the subject consistently moves out of the VP and is presumably located in the Spec of T. Thus, any verb that precedes the subject can be taken as evidence that it has raised to a higher position.

[14]In child-directed French, we expect all verbs that are unambiguously low are nonfinite; otherwise, the utterance would be ungrammatical. Thus, P([−Tense]|Verb low) must approach 1 rapidly for the evidence would be completely one-sided. This, of course, accounts for the other side of the findings in (27) that low verbs are almost always nonfinite.

6.   LEARNING AND UNIVERSAL GRAMMAR

The use of probabilistic learning in the variational model is connected to, and in fact draws insights from, learning problems in other cognitive and perceptual domains (Bush and Mosteller (1958), Herrnstein and Loveland (1975)). However, it is worth stressing that this in no way denies or replaces the critical assumption of UG. After all, the selection of grammars in learning requires a pool of candidates to select *from*, and that is supplied by parameters and UG (see Yang (2002; 2004) for additional discussions). Indeed, an interesting direction for research may focus on the properties of root infinitives and their interactions with the development of the aspect system; see Wijnen (1997), Becker (2000), Hyams (2007/this issue) among others, for an extensive investigation, where it has been observed that most RI usage in child language expresses temporal and modal meanings. For example, Hyams (2007/this issue) argues that RIs in a typologically diverse range of languages are interpreted by the aspectual properties of the predicate. When integrated with our approach to RI, it means that a possible grammar in UG may use either Tense or Aspect to encode temporal meanings—sometimes both, but never neither. If so, then the [−Tense] grammar, when accessed, necessarily has an aspectual interpretation, consistent with the observations in the literature (Austin (2002)). This would further reveal the role of domain-specific linguistic knowledge in language acquisition even if the learning mechanism is domain-general. We leave the exploration of this connection with previous work for future research.

The variational model does raise the possibility that the mechanisms of language acquisition may be part of what Hauser, Chomsky, and Fitch (2002) call the Faculty of Language in the Broad sense (FLB). One direction in which this view can be empirically pursued concerns individual variations in language acquisition. More directly, the model of morphosyntactic learning advocated here may offer an explanation for the extended RI stage in a population of SLI children (Rice and Wexler (1996), Rice, Wexler, and Hershberger (1998)). For us, the extended RI stage is not the result of underlying grammatical deficits. Rather, as has been well documented in the acquisition of past tense (Leonard et al. (1992), Rice, Wexler, Marquis, and Hershberger (2000), and the references cited therein), SLI children may simply be slow morphological learners, which in turns slows down the emergence of the [+Tense] grammar under the current proposal that the frequency-sensitive mastery of language-specific morphology plays a crucial role in the course of grammar elimination. Also of relevance is a group of SLI learners who exercise nontarget but UG-compatible options of grammar (van der Lely and Battell (2003)), precisely replicating the pattern of acquisition in normal developing children (McDaniel (1989), Thornton (1990)). Thus it seems that this specific SLI population are simply slower learners— which can be formally characterized in the variational learning framework by a parameter of learning rate that dictates the amount of punishment/reward in

grammar competition—rather than learners with specific deficits in the core grammatical system.[15] In a theory where the roles of morphological learning and syntactic acquisition are clearly articulated, it may be possible to identify more precisely the source of language learning deficits in the notoriously heterogeneous symptoms of SLI children.

In conclusion, we would like to suggest that both the input data and the mechanisms by which children internalize grammar on the basis of the input data be taken seriously in the generative approach to language acquisition. Doing so in no way diminishes the importance of Universal Grammar, but Universal Grammar does not have to do all the work in order for language acquisition to succeed. Under the contemporary idea that much of language variation (and thus acquisition) comes down to the acquisition of the lexicon, it would seem more pressing to develop a theory of experience-dependent language learning. (If anything is learned, it's words.) For aspects of the grammar that take time to complete (such as the RI phenomenon), it remains a possibility that the child is not receiving a sufficient amount of relevant linguistic evidence: what "counts" as relevant linguistic evidence will inevitably turn to UG, for the child does not simply match and replicate what is presented in the input. It might be added that even for aspects of grammars that children can successfully acquire very rapidly, it is also desirable to have a specific account of the learning mechanism, and how that mechanism makes use of the input data so spectacularly. UG is a biological miracle, but learning needn't be.

ACKNOWLEDGMENTS

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[15]See also Franks and Connell (1996); we thank Steve Franks for pointing out the relevance of their work.

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