Phonological constraints on children's production of English 3rd person singular -*s*

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Running Head: Phonological Constraints on Morpheme Production

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Abstract

Purpose: Children variably produce grammatical morphemes at early stages of development, often omitting inflectional morphemes in obligatory contexts. This has typically been attributed to immature syntactic or semantic representations. In this study we investigated the hypothesis that children's variable production of the 3rd person singular morpheme -*s* interacts with the phonological complexity of the verb stem to which it is attached.

Method: To explore this possibility, we examined longitudinal data from the spontaneous speech of 6 English-speaking children between 1;3-3;6 years, and elicited imitations from a cross-sectional study of 23 2-year-olds (mean age of 2;2 years).

Results: The results showed that children produced 3rd person singular morphemes more accurately in phonologically simple coda contexts (e.g., *sees*) as compared to complex coda contexts (e.g., *needs*). In addition, children produced -*s* more accurately in utterance-final compared to utterance-medial position.

Conclusions: The results provide strong support for the role of phonological complexity in explaining some of the variability in children's production of 3rd person singular -*s*. This suggests that future research will need to consider multiple factors, including phonological and positional effects, in constructing a comprehensive developmental theory of both grammatical competence and processes of speech planning and production.

Keywords: phonology, coda complexity, grammatical morphemes

Introduction

It has long been observed that grammatical morphemes are variably produced in early speech (Bloom, 1970; Brown, 1973). Compare the variable production of the 3rd person singular morpheme -*s* in examples (1a, b), both produced by the same child on the same day.

(1) Naima (2;2.11)

a. Mommy tries (to) do.

[ˈmami ˈtraɪz du]

b. Mommy need(s) to go to the hospital.

[ˈmami nid təgo tədə ˈhaspɪtəl]

Determiners, complementizers, subject-verb agreement and auxiliaries are all considered to be grammatical function (as opposed to content) categories, each with its own syntactic structure (Abney, 1987; Chomsky, 1988). The fact that early stages of language acquisition exhibit variable use of such items has led some researchers to suggest that children's early grammars are syntactically impoverished, fluctuating between syntactic representations (Lebeaux, 1988) or consisting of a bare verb phrase (Guilfoyle & Noonan, 1989). Others propose that certain types of syntactic knowledge become available only as a child biologically matures (e.g., Radford, 1990). In particular, Wexler (1994) argues that children go through an 'optional infinitive' stage of development, where they variably use infinitival, uninflected forms of verbs in contexts where the finite, inflected verb form is required. For instance, a child might say, *"This goes in there,"* and at the same time, *"Patsy need a screw"* (Harris & Wexler, 1996: 11). According to the

Maturation Hypothesis, the occasional use of grammatical morphemes is considered to be syntactically nonproductive. Rather, syntactic competence is considered to be achieved only once the child shows stable use of grammatical morphemes, signalling that the relevant grammatical principle has matured.

A few researchers have tried to determine why children's production of grammatical morphemes might be so variable. Some have taken a semantic approach, noting that the past tense morpheme tends to be produced earlier with accomplishment verbs (e.g., *dropped*) than activity verbs (e.g., *played*) (e.g., Bloom, Lifter & Hafitz, 1980; Johnson & Morris, 2007). Drawing on cross-linguistic data, Hyams (2007) further suggests that children's use of grammatical markings on verbs is sensitive to aspectual distinctions. Thus, it may take children some time to learn how to appropriately mark the semantics of different types of events, and this may account for some of the variable production of inflectional morphemes in children's early speech. Thus, some of the variable production of early grammatical function morphemes might be due to semantic factors.

Other researchers have found that children variably produce grammatical morphemes in different phonological or prosodic contexts (e.g., Gerken, 1996). This would indicate that the locus of some of the variability in morpheme production is due to limitations on children's phonological representation or phonological competence rather than due to a lack of syntactic competence. If this is true, it would suggest that children's knowledge of syntax may be more advanced than typically assumed. It would also suggest that our measures of syntactic competence should take phonological factors into consideration.

In this paper, we investigate whether phonological constraints can be used to predict the contexts in which children are likely to produce or omit 3rd person singular morphemes.

Researchers have long noted that children with specific language impairment (SLI) who have problems with phonology also have problems with the accurate production of grammatical morphemes. For example, Bortolini and Leonard (2000) found that English SLI children were less accurate than MLU-matched controls at producing initial unfooted syllables and word-final coda consonants in monomorphemic words (e.g., *banana, fast*). These same children were also more likely to omit grammatical morphemes involving the use of related phonological structures (e.g., *the car, climbed*). In addition, children with delayed expressive phonological abilities but average receptive vocabulary scores are more likely to omit grammatical morphemes than would otherwise be expected (Rvachew, Gaines, Cloutier, & Blanchet, 2005). These studies indicate a close connection between phonological and morphological development in language-delayed populations. It thus seems promising to explore a phonological explanation for some of the variability found in typically developing children's production of grammatical morphemes.

A phonological approach

A number of findings in the literature support the position that children's phonological limitations contribute to some of the early variability in the production of grammatical morphemes. These results come from cross-linguistic studies of both typically developing children and those with SLI. These studies involve two types of constraints on phonological representations; those often referred to as rhythmic or metrical constraints, and those involving issues of syllable structure complexity. Because both of these occur at levels of phonological structure above that of individual phonemes, we will refer to both types of phonological limitations as *prosodic* constraints. In particular, we propose that children do not randomly omit grammatical morphemes. Rather, we hypothesize that, all else being equal, children will be more likely to produce grammatical morphemes in phonologically (or prosodically) unmarked, or simple contexts. We call this the Prosodic Licensing Hypothesis (Demuth & McCullough, in press). This allows us to make testable predictions about the contexts in which grammatical morphemes will be most likely to appear, both in English, and across languages. We discuss below some of the literature that provides support for the Prosodic Licensing Hypothesis. We first discuss some of the metrical findings (i.e., phrase-level constraints), and then focus on the syllable structure findings (i.e., syllable or word-level constraints), providing a reference point for our study of 3rd person singular -*s*.

Phrase-level constraints on the production of grammatical morphemes

Researchers have previously noted that until around 2;6 years, children learning the southern Bantu language Sesotho tend to omit noun class prefixes, grammatical morphemes which indicate the class/gender of a noun (Connelly, 1984). However, prefixes with monosyllabic stems are consistently produced. Demuth (1992, 1994) proposed that some of the variable production of these grammatical morphemes could be explained in terms of phonological constraints. Specifically, she proposed that noun class prefixes were more likely to be produced when they formed part of a disyllabic foot (e.g., $[\underline{mo}\text{-}tho]_{Ft}$ 'person'), but tended to be omitted when they were unfooted, i.e., when the nominal stem already had two syllables (e.g., $(\underline{mo})\text{-}[sa.di]_{Ft}$ 'woman'). Recent research has shown that this stage of development lasts until around 2;3-2;6 years (Demuth & Ellis, in press).

Similarly, Gerken and colleagues showed that the variable production of English pronominal subjects and articles is partially explained by the different metrical or rhythmic contexts in which these appear (Gerken 1991, 1994, 1996; Gerken & Macintosh, 1993). As in

Sesotho, English articles are more likely to be produced when they can be prosodified as part of a trochaic foot. In contrast, articles are more often omitted when they appear in unfooted contexts. Gerken (1996) claims that this helps explain why 2-year-olds tend to produce footed object articles like that in (2a) more frequently than unfooted articles such as that in (2b).

(2) a. He kicks the piggy.

[S w]$_{Ft}$ [S w]$_{Ft}$

b. He catches (the) piggy.

[S w]$_{Ft}$ w [S w]$_{Ft}$

More recently, Demuth and McCullough (in press) examined the emergence of articles in five English-speaking 1- to 2-year olds by looking at longitudinal, spontaneous speech data. They confirmed Gerken's (1996) findings from elicited imitation tasks, showing that children were more likely to produce articles when these occurred as part of a trochaic foot than when they appeared in an unfooted context.

Similar findings have also been reported in a longitudinal study of two children learning French, where foot structure is iambic rather than trochaic (Demuth & Tremblay, 2008). In all cases the limiting factor was shown to be children's lack of prosodic organization at the level of the phonological phrase (see Demuth & Tremblay, 2008; Gerken, 1996, for reviews). Taken together, the findings from these metrically different languages show that some of the variability in children's early production of grammatical morphemes may be explained in terms of rhythmic constraints.

Sensitivity to rhythmic constraints may also explain why Italian-speaking SLI children exhibit an extended period of variable production of articles (Leonard, Bortolini, Caselli, & Sabbadini, 1993). Given that there are few monosyllabic words in Italian, most articles are unfooted. The Prosodic Licensing Hypothesis would therefore predict that Italian articles would be especially vulnerable to omission until children develop competence with more complex, higher-level prosodic structures. Similar issues appear to be relevant for understanding the variable production of articles in Spanish and German (Lleó & Demuth, 1999; Demuth, 2001; Lleó, 2001). We now turn to a discussion of findings on syllable-structure constraints, and the implications for the acquisition of inflectional morphemes.

Syllable-level constraints on the production of grammatical morphemes

Besides being affected by rhythmic constraints, there is also evidence that children's productions of grammatical morphemes are affected by syllable-level constraints. For example, before typically developing children can reliably produce inflectional morphemes like the plural morpheme -*s* in a word such as *cats*, it is necessary that they have the ability to produce word-final /ts/ (Bernhardt and Stemberger, 1998). Thus, children's phonological grammars need to be able to handle certain types of coda consonant clusters before they begin to produce inflectional morphemes.

Oetting and Horohov (1997) and Johnson and Morris (2007) found that young children with and without language impairment were more likely to inflect past tense verbs ending in a non-obstruent consonant (e.g., *rolled*) than verbs ending in an obstruent (e.g., *walked*). Thus, the sonority of the stem-final coda consonant or the sonority hierarchy of coda consonant clusters may also have an impact on the production of inflectional morphemes.

Furthermore, in one of the early studies investigating children's knowledge of inflectional morphology, Berko (1958) found that children were more likely to produce the past tense morpheme in verbs that ended in a non-coronal consonant (e.g., *kicked*) than in those that ended in coronal consonants /t, d/, where syllabic *-ed* is required (e.g., *wanted*). Thus, adding another syllable to the inflected word is apparently more difficult than having a consonant cluster (see similar findings by Marchman, Wulfeck, & Weismer, 1999).

Most relevant to the present study is an investigation of 9 to16-year-old Grammatical-SLI children, where Marshall and van der Lely (2007) investigated the impact of the number of consonants at the end of the inflected verb on the production of past tense inflections. Using an elicited production task, subjects were found to have increasing difficulty producing past tense morphemes as word-final consonant complexity increased from one to three consonants (e.g., *sewed* /soʊd/, *yelled* /jɛld/, *danced* /dænst/). Thus, the number of consonants at the end of the word, that is, an increase in coda consonant complexity, helps to explain some of the variable production of the past tense morpheme in Grammatical-SLI children.

Other factors affecting the production of grammatical morphemes

Besides constraints on rhythm and syllable-shape, children's production of grammatical morphemes is also likely to be affected by frequency of occurrence, position in the utterance, and the length of the utterance. There is evidence that the frequency of inflected plurals in the input children hear is a good predictor of their likelihood of producing plural *-s* (Zapf, 2004). Further attesting to the role of input statistics, several studies have shown that both typically-developing children (Edwards & Beckman, 2008; Edwards, Beckman, & Munson, 2004; Munson, 2001; Storkel, 2001; Zamuner, Gerken, & Hammond, 2004) as well as those with SLI (Munson, Edwards, & Beckman, 2005; Munson, Kurtz, & Windsor, 2005) repeat novel words with high-probability phoneme sequences more accurately than those with low-probability sequences. In addition, many of these studies indicate that children with smaller vocabularies are more likely to be affected by input statistics than children with larger vocabularies. Given these findings, it is possible to predict that frequency (or the phonotactic probability) of the inflected form might account for some of the variable production of inflectional morphemes.

Still others have found that the prosodic characteristics of words in different positions within the utterance may influence children's abilities to both perceive and produce grammatical inflections. For instance, using a sentence imitation task, Dalal and Loeb (2005) found that SLI 5-year-olds were more likely to produce the past tense *-ed* morpheme in utterance-final as opposed to utterance-medial position. The authors suggest that the higher perceptual salience of words or morphemes in utterance-final position due to final lengthening facilitates morpheme processing and production in imitation tasks. In addition, Kirk and Demuth (2006) showed that coda consonants are more reliably produced in syllables with longer duration. Thus, there may be more time to complete the full articulation of coda consonants in longer syllables, such as those at the end of an utterance.

Of particular interest in this study is the unique distribution of 3rd person singular *-s* in parental speech. Leonard and colleagues have raised the possibility that inflectional morphemes might be especially vulnerable and likely to be omitted due to the fact that they are composed of phonetically short elements that might be difficult to perceive. This problem is exacerbated in the case of English verbs, since these tend to occur utterance-medially in parental speech, whereas plural nouns tend to occur utterance-finally (Hsieh, Leonard, & Swanson, 1999). Hsieh et al. (1991) report that, as a consequence of this difference in distribution, 3rd person singular *-s* is much shorter in duration compared to plural -*s*, perhaps reducing the perceptional salience of the 3rd person singular morpheme. They suggest that this distributional difference may help explain some of the differences in the rate of acquisition of plural -*s* versus 3rd person singular -*s*.

Finally, some researchers suggest that processing factors may account for some of the variability in the production of grammatical morphemes. Specifically, longer utterances require greater processing load – in their planning as well as articulation. An increase in processing load, in turn, may lead to less efficiency in producing speech. A speaker is thus more likely to make speech errors in longer utterances, often omitting some linguistic constituents in a way to reduce processing demands (Bloom, 1990; Valian, 1991). For example, Valian (1991) found that English-speaking children between ages of 1;10 and 2;8 were more likely to omit grammatical morphemes such as pronominal subjects in longer utterances. This suggests that the increased length of an utterance, which may also include greater grammatical complexity, can have a detrimental effect on morpheme production.

Predictions for children's acquisition of 3rd person singular -s

Despite its high variability in children's early speech and its importance in recent work on the locus of grammatical problems in children with SLI (e.g., Rice & Wexler, 1996), there has been little research examining possible phonological constraints on the acquisition of 3rd person singular -*s*. Children typically acquire 3rd person singular morphemes relatively late (Brown, 1973), showing variable production of this morpheme until around the age of 3-4, and longer in children with SLI. The goal of this study was therefore to better understand why the 3rd person singular morpheme -*s* is so variable in children's early speech, and if phonological complexity at the level of the syllable might account for some of this variability.

Following Clements and Keyser's (1983) work on syllable structure[1], we will refer to final consonant+s coda clusters (e.g., *needs*) as phonologically 'more complex' than singleton -*s* codas (e.g., *sees*). It is generally assumed that linguistically more complex forms are more challenging for children to acquire or produce (Bloom, 1970; Brown & Hanlon, 1970; Kamhi, Catts, & Davis, 1984). In particular, researchers have noted that words with simple syllable structures appear earlier in development, with singleton -*s* codas (CVC) being acquired earlier than consonant cluster codas (CVCC) (e.g., Levelt, Schiller, & Levelt, 2000). Thus, we predict that children will show better performance in the production of 3rd person singular morphemes when these occur as part of a phonologically simple (singleton - C) coda than a phonologically more complex (cluster - CC) coda. That is, we expect to find that children who exhibit variability in their production of 3rd person -*s* will be more likely to produce this morpheme in words such as *sees* than in words such as *needs*.

To address this issue we first examined longitudinal data from 6 English-speaking children's spontaneous productions from 1;3 to 3;6 years. We then confirmed and elaborated on our findings in a more controlled, cross-sectional, elicited imitation study with 23 2-year-olds (aged 1;10-2;4).

Experiment 1: Longitudinal study

Brown (1973) reports that many grammatical morphemes are acquired between 1 and 3

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[1] According to some accounts of syllable structure, liquids and nasals followed by -*s* can be syllabified as part of a branching coda, whereas obstruent+s clusters, which violate the sonority sequencing principle, must be syllabified as a singleton coda consonant plus an -*s* appendix, at the higher level of the syllable (Selkirk, 1982; see Kirk & Demuth, 2005, for discussion). However, in a cross-sectional study using a picture identification task, Kirk and Demuth (2005) found that 2-year-olds produced nasal+s and obstruent+s clusters equally well. Thus, both types of consonant+s clusters appear to be acquired at similar developmental periods, regardless of their structural realization within the syllable. For simplicity, we will refer to both types of consonant clusters as *codas* in the present study.

years. However, it is often difficult to test children below the age of 2 in elicited imitation tasks. Therefore, examining longitudinal, spontaneous production data can be particularly useful when investigating children's early use of grammatical morphemes. Furthermore, looking at spontaneous data provides a rich source of information about how children typically produce grammatical morphemes in a natural environment. In this longitudinal study we provide information about individual patterns of 3rd person singular morpheme development in children between ages 1;3-3;6, paying particular attention to the role of coda complexity. We also examined the contribution of phonological constraints relative to the role of the position of the morpheme within the utterance (medial vs. final), utterance length (in words), Mean Length of Utterance (MLU) (in morphemes) and the frequency of the inflected form of the verb in child-directed speech.

Method

The database and participants

The data examined in this study were drawn from the Providence Corpus (Demuth, Culbertson, & Alter, 2006), a longitudinal corpus consisting of spontaneous speech interactions between 6 mother-child dyads from southern New England in the United States (for further information and access to the corpus, see CHILDES http://childes.psy.cmu.edu/). The profiles of the six children are shown in Table 1 along with their gender, age range studied, and MLU in morphemes. All six children were typically developing, monolingual speakers of American English. The parents of two children (Alex, Violet) spoke a dialect typical of southern New England, which is often characterized by the omission of post-vocalic /ɹ/. The parental input for the other four children more closely resembled Standard American English.

[insert Table 1 about here]

Digital audio and video recordings were collected in the children's homes for approximately 1 hour every two weeks for 2 years, from the onset of first words. The digital audio and video data were downloaded onto a computer, and both mother and child speech were orthographically transcribed using CHAT conventions (MacWhinney, 2000). The child utterances were also transcribed by trained coders using IPA transcription showing the phonemic representations of words and the position of stressed syllables. Ten percent of the child data from each recording session were re-transcribed by a second coder. Percent segmental agreement between the two transcribers ranged from 85-95%. Most of the disagreements were in vowel quality, though some involved place/manner of consonant articulation. Differences in voicing were not counted because young children's voicing is not stable enough to accurately transcribe (Stoel-Gammon & Buder, 1999). Two-year-olds' production of coda consonants has been shown to be affected by the position of a coda within the word, word length, and stress (Kirk & Demuth, 2006). We therefore limited our investigation to children's production of 3rd person singular morphemes in monosyllabic words.

Procedure

Using discourse context as well as phonological cues (Vihman & McCune, 1994), we first extracted from the Providence Corpus all child target 3rd person singular monosyllabic verbs where the stem had either no coda consonant (e.g., *sees*) or one coda consonant (e.g., *needs*). Thus, 3rd person singular -*s* appeared in either simple (C) or more complex (CC) coda contexts.

Verbs ending in CCC were few, and were therefore not considered in this study. To avoid issues of r-less dialect and a tendency to vocalize word-final /ɹ/ and /l/, words ending in a liquid were excluded from the analysis (25 tokens).

Then we further excluded all target words followed by vowel-initial words (207 tokens) (e.g., *It goes in there* [ɪ ˈgozɪn ˈdeɪɛ]). We did this to avoid possible issues of re-syllabification where a coda consonant becomes the onset of a following syllable. In general, such re-syllabification is known to occur only when the following syllable begins with a vowel, suggesting that this might be a strategy to avoid onset-less syllables (Kenstowicz, 1994). Because it is unlikely that the word final *-s* is re-syllabified as an onset of the following consonant-initial word, only target words followed by consonant-initial words were analyzed.

We also excluded immediate repetitions, target words followed by a word beginning with *s-* (5 tokens) (e.g., *But he looks small to me* [bə ɪˈlʊk ˈsmatə ˈmi]), and the few cases where it was impossible to distinguish between words in the production (2 tokens) (e.g., *He needs to go to the office* [inigələtudə ˈafɪ]). Items with poor acoustic quality were also excluded (7 tokens).

Data analysis began for each child from the point when they targeted the first 3rd person singular verb. Data analysis terminated at 2;6 years or as soon as 3rd person singular *-s* was successfully produced at least 80% percent of the time in simple C contexts across 2 consecutive sessions (3 children). In cases where this criterion was not reached (3 children), analysis continued until the end of data collection (around 3;6).

The resulting dataset included 323 verb tokens (11 verb types) in simple C contexts and 284 verb tokens (40 verb types) in complex CC contexts (see Appendix A and B, respectively). Among the 323 tokens in simple C contexts, 225 tokens (70%) occurred in utterance-medial position and 98 tokens (30%) occurred in utterance-final position. As for the 284 tokens in complex CC contexts, 211 tokens (74%) and 73 tokens (26%) occurred in utterance-medial position and utterance-final position, respectively.

These items were then coded either as -*s produced* or -*s missing* depending on whether the 3rd person singular morpheme -*s* was present or not (see Table 2). For words ending with a singleton -*s* (simple C context), -*s missing* indicated that the target morpheme was either missing or substituted with another consonant (e.g., *goes* [go], [gop]). However, substitution of /s, z/ with /ʃ/, /θ/ or /ʒ/ was counted as -*s produced* because studies have shown that these consonants are often interchangeable with /s/ and /z/ in early speech (Bernhardt & Stemberger, 1998). Verbs ending with consonant clusters (complex CC context) were coded as -*s produced* if final /s, z/ was present, regardless of whether the consonant of the verb stem was present, reduced, or substituted (e.g., *looks* [lʊks], [lʊs], or [lʊts]). The few tokens with consonant epenthesis were also coded as -*s produced* (e.g., *looks* [lʊksk]). In contrast, a verb was coded as -*s missing* if a cluster was entirely deleted (e.g., *looks* [lʊ]) or if -*s* was missing (e.g., *looks* [lʊk], [lʊp]).

[insert Table 2 about here]

Results

Chi-square: Group and Individual Results

Overall, the six children produced 3rd person singular -*s* more often in simple C contexts as compared to complex CC contexts (75% vs. 54%). The result from a chi-square test indicated that this difference was highly significant ($\chi^2 = 29.47$, $df = 1$, $p < 0.001$). This supports our hypothesis that word-final morpheme production is affected by coda consonant complexity.

Further analysis of individual children's performance showed that four of the six children were more likely to produce 3rd person singular morphemes in the phonologically simple C contexts than in complex CC contexts (Alex: $\chi^2 = 5.65$, $df = 1$, $p = .017$; Ethan: $\chi^2 = 15.02$, $df = 1$, $p < 0.001$; Naima: $\chi^2 = 7.00$, $df = 1$, $p = .008$; Violet: $\chi^2 = 4.20$, $df = 1$, $p = .040$). Two children showed no difference in performance between the two contexts (Lily: $\chi^2 = .08$, $df = 1$, $p = .776$; William: $\chi^2 = .17$, $df = 1$, $p = .678$). Lily was at ceiling, showing high accuracy on the production of 3rd person singular -*s* in both simple and complex contexts (C: 82% vs. CC: 80%). In contrast, William showed overall poor performance on the production of 3rd person singular morphemes (C: 57% vs. CC: 51%).

Table 3 provides a longitudinal picture of how individual children produced 3rd person singular morphemes in each phonological context. The data are grouped into four-month intervals. Here as well, it can be seen that the four children who showed a complexity effect exhibited a gradual increase in morpheme production accuracy over time, generally becoming more accurate in simple C contexts first. In contrast, Lily showed high levels of accuracy from the onset of her first verbs. William's development of 3rd person singular was slower than that of other children. He also produced very few target 3rd person singular verbs overall.

[insert Table 3 about here]

Thus, the children in the longitudinal study were less accurate at producing 3rd person singular -*s* when the morpheme was part of a complex coda cluster. These results indicate that the production of the 3rd person singular morpheme in typically developing children is subject to coda complexity effects similar to those reported for older Grammatical-SLI children's production of past tense morphemes (Marshall & van der Lely, 2007).

Logistic Regression: Group Results

To explore the relative contributions of phonological, processing, and lexical factors, we conducted a stepwise logistic regression analysis. Logistic regression is ideal when some continuous and some categorical factors are used as predictors of a dependent variable that is binary. Six hundred and seven 3rd person singular verb tokens (C: 323, CC: 284) from 6 children were used as individual data points in a logistic regression analysis. The dependent variable was either -*s produced* or -*s missing*. There were nine independent variables that were examined: (a) two categorical factors - coda complexity and position of the verb within the utterance; (b) three continuous factors - utterance length (in words), frequency of the inflected verb, the child's MLU (in morphemes); (c) and four interactions - complexity*length, complexity*frequency, complexity*position, position*length.

In stepwise logistic regression, analysis begins with a model with no factors, including just a constant (step 0). At each step, the most significant term is added to the model until none of the factors left out of the model would have a statistically significant contribution if they were added to the model (step 5). The results are shown in Table 4, and discussed below. Together, these factors were able to correctly predict 67.9% of 3rd person singular -*s* productions by the 6 children.

[insert Table 4 about here]

Coda complexity

As shown in Table 4, coda complexity was the first factor entered into the model indicating that of all the factors, coda complexity was most effective in predicting the contexts where 3rd person singular -*s* was produced correctly. The negative sign on the coefficient *B* confirms that with increasing coda complexity, children's ability to produce 3rd person singular -*s* decreased. This result is consistent with the chi-square test, which examined coda complexity as a single independent variable. Thus, coda complexity appears to play an important role in the production of 3rd person singular morphemes even when the effects of other factors are taken into consideration. This provides additional support for our hypothesis that phonological complexity accounts for some of the variability in children's early production of this morpheme.

Position within the utterance

In addition to coda complexity, we examined whether the position of the 3rd person singular morpheme within the utterance influenced children's production of 3rd person singular -*s*. In subject-verb-object languages like English, children hear 3rd person singular verbs more often in utterance-medial position than in utterance-final position (Hsieh, Leonard, & Swanson, 1999). Similarly, we found that 72% of the children's attempted 3rd person singular verbs in this study occurred in utterance-medial position. Of these 436 tokens, about half were verbs with simple C structure (225 tokens), and half were verbs with more complex CC structure (211 tokens). Thus, although children's early utterances often consist of only a few words, most of their attempted 3rd person singular verbs occurred in utterance-medial position, and this was balanced across complexity.

Given the high frequency of utterance-medial 3rd person singular verbs in parental speech

(Hsieh et al., 1999), we might have expected children to accurately produce 3rd person singular -*s* in utterance-medial position. As shown in Table 4, morpheme production was significantly influence by position: however, the coefficient indicates that children produced fewer correct 3rd person singular morphemes in utterance-medial position. Thus, similar to Dalal and Loeb's (2005) findings of past tense -*ed* morpheme production by 5-year-old SLI children, the typically-developing children in this study were also more likely to produce 3rd person singular -*s* utterance-finally. Not surprisingly, the effects of position were also greater with increased utterance length, as confirmed by a significant interaction. Thus, children had greater difficulty producing utterance-medial 3rd person singular -*s* in longer sentences.

As discussed in the Introduction, the poorer performance in medial position could be due to the fact that phrase-medial words in English are typically shorter in duration than those in phrase-final position (Hsieh, et al., 1999). Children begin to exhibit phrase-final lengthening like adult speakers around the time that they begin to combine words (Snow, 1994, 1998). It is therefore likely that the increased duration in phrase-final position provides more time for children to produce segments at the end of a word, facilitating final consonant (and morpheme) production. Similarly, Kirk and Demuth (2006), in a study of tautomorphemic word-internal and word-final coda consonants found that these were most likely to be produced by children in word-final syllables or word-medial stressed syllables. They suggest that this may be due to the increased duration in both types of syllables, perhaps providing more time for young speakers to produce the coda consonant.

Utterance Length

Third person singular morphemes are relatively late acquired compared to other grammatical morphemes (Brown, 1973). It is therefore likely that these morphemes are used in syntactically complex structures in longer utterances. This might increase the overall processing and planning load, leading to morpheme omission in longer utterances (e.g., Valian, 1991).

In order to investigate the possible effects of processing load on children's production of 3rd person singular -*s*, we counted the number of words in each utterance and examined whether -*s* was more likely to be omitted with increasing utterance length. The length of these children's utterances ranged from 1 word to 21 words, with a mean length of 4.58 words (*SD* = 2.65). The results in Table 4 confirmed that the children's production of 3rd person singular morphemes was adversely affected by utterance length, with children producing 3rd person singular -*s* less frequently in longer utterances.

Inflected frequency

Lexical frequency factors might also help explain why children were good at producing 3rd person singular morphemes only in some tokens. Young language learners are known to be sensitive to the frequency of various linguistic structures. For example, Zapf (2004) found that normally developing 2-year-olds produced plural nouns more accurately when the inflected form was frequent in the input (e.g., *books, shoes, dogs*). Oetting and Rice (1993) report similar findings for children with SLI. That is, nouns that are frequently pluralized in everyday speech, such as *dogs* and *doors*, were more readily inflected than nouns that are infrequently pluralized (e.g., *stoves, clocks*).

We therefore examined whether children's production of 3rd person singular -*s* may have been affected by inflected frequency in the input. To determine inflected frequency, we consulted the CHILDES database (MacWhinney, 2000). The CHILDES Parental Corpus contains around 2.6 million word tokens and 24,000 word types used in child-directed speech. If input frequency accounts for some of the variability in the production of 3rd person singular morphemes, children should be more accurate at producing 3rd person singular -*s* for verbs that are frequently inflected in parental input. However, the results of the logistic regression indicated no advantage for frequent 3rd person singular verbs. There was no significant contribution of inflected frequency nor was there a significant contribution of the interaction of complexity and inflected frequency.

Further investigation would be needed to explain why children's production of 3rd person singular morphemes might not benefit from an increase in lexical frequency. Hsieh et al. (1999) showed that 3rd person singular morphemes in utterance-medial position are likely to have short durations, even in mothers' speech. If 3rd person singular morphemes are less perceptually salient in the speech input to children, perhaps they are less likely to benefit from the high frequency of the morpheme. In contrast, it might be easier for children to take advantage of the frequency of morphemes such as plural -*s* because these often occur in utterance-final position, where they are typically lengthened. Alternatively, it is possible that the aggregate inflected frequencies presented in the CHILDES database are not a good estimate of the frequency with which these particular children heard these words.

MLU

The last factor that we examined was MLU, calculated by averaging the number of morphemes over the whole utterances produced by each child. Because MLU is a common measure of linguistic ability in children, we predicted that a child who had low MLU would also show poor performance in producing 3rd person singular morphemes. The results in Table 4 confirmed this prediction: children's increasing ability to produce 3rd person singular *-s* was significantly correlated with increasing MLU. This indicates that there is a strong correlation between children's general language abilities and their production of 3rd person singular morphemes.

Discussion

In sum, the logistic regression showed that the production of 3rd person singular *-s* was influenced by coda complexity, position within the utterance, utterance length, the interaction of position and utterance length, and MLU. Frequency of inflected form, however, failed to explain children's production pattern for 3rd person singular *-s*.

The patterns found in children's production of 3rd person singular -*s* could be also explained by factors other than those considered in the model. Here we discuss some of the possible factors. Because there was a larger type inventory for the verbs in CC contexts than in C contexts (see Appendix), it is likely that children produced the same verbs in the C contexts repeatedly. If so, the reduced number of errors in C contexts may be due to practice effects. To investigate this possibility, we divided the verbs in the simple C context into high token frequency verbs (over 80 occurrences; e.g., *goes*, *says*), and low token frequency verbs (under 10 occurrences; e.g., *sees*, *tries*) in children's own production. Surprisingly, children accurately produced only 74% of the high token frequency verbs, whereas they produced 87% of low token frequency verbs. Thus, we think it is unlikely that simple practice effects can account for children's greater accuracy in simple C compared to complex CC context.

Another factor to be considered is the phonological context of the word following 3rd singular *-s* in utterance-medial position. For instance, one might wonder whether 3rd person singular morphemes are more accurately produced when they are followed by function words than content words, given that function words are often unstressed and can perhaps re-syllabify with the preceding syllable. However, function words in the current study occurred with comparable frequency following utterance-medial 3rd person singular -*s* in simple C (36%) and complex CC (29%) contexts.

Finally, because 3rd person singular verbs were always followed by consonant-initial words, the utterance-medial position in the present study can also be seen as a context with greater phonological complexity. If utterance-position is the primary factor mediating phonological complexity, we might expect an equally accurate production of 3rd person singular -*s* in utterance-medial simple C contexts (e.g., *sees him*) and utterance-final complex CC contexts (e.g., *needs*), as both induce CC phonological contexts. However, our results suggest that the effect of coda complexity overrides that of phrasal complexity; that is, children produced the 3rd person singular morphemes more accurately in utterance-medial simple C contexts (72%) even compared to utterance-final complex CC contexts (58%). This difference was significant (χ^2 = 5.71, *df* = 1, *p* = .02). At the same time, as shown by the logistic regression analysis, children's production of 3rd person singular -*s* was also affected by utterance position. We expect that further acoustic analysis of utterance-medial 3rd person singular verbs, in both child and parent speech, will provide a more comprehensive understanding of why children's production of 3rd person singular -*s* is adversely affected in utterance-medial position.

Summary: Longitudinal Study

The longitudinal study examined the possible effects of coda complexity on the variable production of 3rd person singular morphemes in children's spontaneous speech. Chi-square analyses of the data from individual subjects showed that four out of six children were significantly better at producing 3rd person singular morphemes in simple C compared to complex CC contexts. Among the two children who showed no effects of complexity, William was still at the early stages of acquiring 3rd person singular morphemes; he showed overall low performance and attempted few 3rd person singular verbs. In contrast, Lily was highly accurate at producing 3rd person singular morphemes in both simple C and complex CC contexts, showing little variability. The logistic regression analysis showed that the variability in children's early production of word-final grammatical morphemes can be explained by multiple factors, with coda complexity significantly influencing children's production of 3rd person singular -*s*.

The results of the longitudinal study highlight the role of phonological constraints in understanding children's variable production of English inflectional morphology. The results also suggest that children's grammatical knowledge of the 3rd person singular may be better than often assumed. That is, if children can produce 3rd person singular -*s* more reliably in phonologically simple contexts, this would indicate that some of the variable production of this morpheme may be due to phonological rather than syntactic limitations. The fact that this morpheme was also less reliably produced in utterance-medial compared to utterance-final position also suggests that perceptual salience and/or prosodic aspects of utterance position will need to be considered in assessing children's grammatical competence.

To explore these issues further, with more children, we designed the following cross-sectional elicited imitation study, where sentence length and lexical frequency were controlled. Because verbs in English tend to occur in utterance-medial position, another goal of the cross-sectional study was to further explore the effects of utterance position on the production of 3rd person singular -*s*.

Experiment 2: Cross-sectional study

The goal of the cross-sectional study was to determine the robustness of the coda consonant complexity effect on children's production of 3rd person singular -*s*. We also wanted to further investigate the effect of the position of 3rd person singular -*s* within the utterance. From Table 3, it is evident that by 2;0, most children have started producing 3rd person singular -*s* in some, but not all contexts. Thus, children around this age were expected to show variability in their production of 3rd person singular -*s*. Therefore, in the cross-sectional study we tested 2-year-olds using an elicited imitation task similar to that used in Gerken (1996).

Consistent with the longitudinal study, target 3rd person singular verbs in the cross-sectional study were monosyllabic. The target verbs varied in coda complexity (simple C vs. complex CC) and in the position within an utterance (utterance-medial vs. utterance-final). Sentence length and lexical frequency were controlled: All sentences were 3 words (and 3 syllables) long and the inflected verbs were selected to be highly frequent, both in the input children typically hear, and in child productions.

Based on the results from the longitudinal study, we predicted that 2-year-olds would produce 3rd person singular -*s* more often in simple C contexts than in complex CC contexts. We also predicted that children would produce 3rd person singular -*s* more often when target verbs occurred in utterance-final compared with utterance-medial position.

Method

Participants

Participants were 23 full-term, monolingual English-learning 2-year-olds (12 girls, 11 boys). The children ranged in age from 1;9.30 to 2;4.16, with a mean age of 2;2 years. According to parental report, the children had normal hearing and vision, and good health; none of the children had a cold or an ear infection on the day of testing. An additional 21 children were tested but were excluded from analysis either because they did not attempt any sentences (n=19) or attempted less than 8 out of 16 target sentences (n=2). The attrition rate, although high, was quite consistent with previous literature; depending on the nature of the elicited imitation task, attrition rates often range between 25-50% (e.g., Gerken, 1996). Furthermore, all the children in the cross-sectional study had previously performed a comprehension/looking task for another experiment (Sundara, Demuth, & Kuhl, in preparation). This task was easy, requiring only that the child listen and look. In contrast, the elicited imitation task that followed required the children to actively produce sentences. The preamble to production tasks typically involves looking at a picture book with the experimenter, where the child is encouraged to identify objects. In such cases, the child has already begun to talk before the elicited production task begins. In the present study, however, the picture book warm-up task was omitted in an effort to keep total test time to a minimum, and we suspect that this resulted in a higher attrition rate than might otherwise have been expected. Because we were interested in the factors that might account for the variability in production of 3rd person singular -*s*, seven children who were either at ceiling or floor (i.e., over 90% or below 10% correct) were excluded from the analysis.

Stimuli

Twenty target sentences were used in an elicited imitation task to examine children's production of 3rd person singular morphemes in various contexts. Of the twenty sentences, four were fillers with a plural 3rd person subject (e.g., *There they play*), where the use of 3rd person singular -*s* would be ungrammatical. Because the participants made no errors of commission, i.e., overgeneralization of 3rd person singular -*s* on the plural filler sentences (e.g., *There they plays*), the fillers are not discussed further.

The remaining 16 target sentences contained high frequency pictureable action verbs containing either a simple C coda (*blows, cries, flies, throws*) or complex CC coda (*drives, eats, runs, sleeps*). The target verbs were embedded either in medial or final position in 3-syllable, 3-word sentences with a 3rd person singular subject (e.g., *He cries now, There he cries*). These sentence frames were constructed to contain intransitive verbs with a pronominal subject, followed by a consonant-initial adjective. These particular verbs were also selected to ensure that the children in our study would be likely to comprehend, and therefore produce the inflected forms. Verb familiarity was determined in part by examining children's MacArthur CDI comprehension scores of each target verb at 16-months (1;4), and production scores at 16 and 24 months (1;4 and 2 years) (Dale & Fenson, 1996), but primarily using information from the CHILDES database regarding inflected (and non-inflected) verb frequency in child-directed speech (Li & Shirai, 2000; MacWhinney, 2000). In particular, we selected pictureable activity verbs with comparable inflected frequency in the input that the children were likely to comprehend and produce. This information is presented in Table 5.

[insert Table 5 about here]

To determine whether there were systematic differences in input frequency of target verbs with simple and complex codas, the effect of coda complexity (simple, complex) on inflected and non-inflected frequency from the CHILDES database was tested with two separate t-tests. There was no significant effect of complexity on either inflected ($t(6) = -1.88$, $p = 0.11$) or non-inflected frequency ($t(6) = -1.07$, $p = 0.33$) indicating that simple C and complex CC verb stimuli were matched for input frequency. Thus, despite the fact that the verbs *eat* and *eats* appear to have a higher frequency than other verbs in comprehension, production, and input, this provided no overall frequency advantage for the verbs ending in a complex CC coda.

A 36-year-old, female native speaker of American English who is also a trained musician read the 16 target and 4 filler sentences in an animated voice. Sentences were recorded in a soundproof booth using a Shure SM81 table-top microphone. All sentences were digitized at a sampling frequency of 44.1 KHz and 16-bit quantization, and were excised using PRAAT (Boersma & Weenink, 2005). Target sentences had an average duration of 1.85 seconds (Range: 1.41-2.6) and a mean f0 of 229 Hz (Range: 191-263). Each stimulus sentence was then paired with an animated cartoon of a person performing the action (e.g., crying, running). The cartoons were screened for good action-verb association by both adults and 2-year-olds, ensuring that the elicited imitations would have a referential context.

In order to examine the acoustic cues signaling 3rd person singular morphemes in target sentences, the onset and offset of *-s* and the onset and offset of the preceding vowel were identified using a waveform supplemented by a spectrographic display in PRAAT. Following Munson (2004), the onset of *-s* was defined as the onset of high-frequency aperiodic noise; the offset was defined to be the end of the aperiodic noise. The onset and offset of the vowel was visually identified as the onset and offset of abrupt change in the spectrogram and amplitude of the waveform.

The duration of 3rd person singular -*s* and the preceding vowel in each target test sentence is provided in Table 6. To probe for systematic acoustic differences among the 4 sets of sentences, a two-way repeated-measures ANOVA was carried out with coda complexity (simple, complex) and sentence position (medial, final) as independent variables and duration of '-*s*' as the dependent variable. Only the main effect of sentence position was significant, $F(1, 3) = 40$, $p = 0.008$. Specifically, sentence-final -*s* (202.4 ms) was longer than sentence-medial -*s* (125.1 ms). The main effect of complexity was not significant, $F(1, 3) = 5.4$, $p = 0.11$; the interaction between complexity and position was not significant either, $F(1, 3) = 0.58$, $p = 0.5$.

Similarly, another two-way repeated-measures ANOVA was carried out with coda complexity (simple, complex) and sentence position (medial, final) as independent variables and duration of preceding vowel duration as the dependent variable. There was a significant main effect of complexity, $F(1, 3) = 23.8$, $p = 0.02$, and sentence position, $F(1, 3) = 63.9$, $p = 0.004$. The interaction of complexity and position was also marginally significant, $F(1, 3) = 11.1$, $p = 0.045$. In post-hoc tests, 4 pair-wise comparisons were made and following Bonferroni's correction, the α-level was adjusted to 0.012 (0.05/4). In simple C context, the average duration of the preceding vowel was significantly shorter sentence-medially (*Mean* = 372 ms; *SD* = 88) compared to sentence-finally (*Mean* = 642; *SD* = 163), $t(3) = -5.7$, $p = 0.011$. Similarly, in complex CC context, the average preceding vowel duration was significantly shorter sentence-medially (*Mean* = 208; *SD* = 73) compared to sentence-finally (*Mean* = 300, *SD* = 98), $t(3) = -6$, $p = 0.009$. Finally, in sentence-medial position, the preceding vowel duration was significantly shorter in complex CC verbs than in simple C verbs, $t(3) = -5.8$, $p = 0.01$. In contrast, in sentence-final position, there was no significant difference in vowel duration in simple C and complex CC verbs, $t(3) = 4.4$, $p = 0.02$.

To summarize, the vowel duration of verbs in C contexts was overall longer than those in CC contexts, which is probably due to the fact that vowels in *blows*, *cries*, *flies*, and *throws* are followed by a voiced coda -*z*. Those vowels also have either a diphthong or long/tense vowel. On the other hand, the vowels in three of the CC target words are either followed by a voiceless coda (eats, sleeps) or have a short/lax vowel (runs). But most pertinently, the duration of the 3rd person singular '-*s*' was comparable in C and CC contexts; and the duration of the 3rd person singular '-*s*' as well as preceding vowel duration were shorter sentence-medially compared to sentence-finally.

[insert Table 6 about here]

Procedure

Children participated in two tasks - a perception task (10 minutes), followed by the production task (30 minutes). The results from the perception task are reported elsewhere (Sundara, Demuth, & Kuhl, in preparation). For the production task, children were invited into a soundproof test room with the experimenter, and were asked to put on a child-sized backpack with an Azden 31LT FM wireless microphone clipped to it. This was done to ensure good acoustic quality of the recording. In the few cases where the child refused to wear the backpack, it was placed on the table and the microphone was clipped to the child's collar. The children were then invited to sit in the child-sized chair at the table and watch animated cartoons on the computer monitor. The parent sat next to the child, and the experimenter sat across the table from the child, advancing the cartoons one at a time from a laptop computer.

The target sentences were randomized and presented at a comfortable listening level over loudspeakers placed on the table. The child was then asked to listen and repeat what they heard. The first two sentences were 'warm-up' sentences (repeated if necessary) to ensure that they understood the task. Each child was then given a maximum of 4 chances to repeat a given target sentence. If the child failed to attempt the target sentence, the experimenter moved on to the next sentence. The experimenter encouraged the child's performance with praise and stickers for both correct and incorrect productions. Finally, parents were given the MacArthur CDI short form (Vocabulary Checklist: Level II, Form A) to obtain a quick measure of the child's vocabulary size (Fenson, Pethick, Renda, Cox, Dale, & Reznick, 2000).

Coding of children's productions was identical to that used in the longitudinal study, as either *-s missing* or *-s produced*. A trained coder listened to the children's utterances over headphones and transcribed them phonetically. A second coder re-transcribed data from 3 of the children, resulting in 90% agreement regarding the presence of 3rd person singular -*s*. Items containing an epenthetic vowel (5 tokens) (e.g., *He flies fast* [hi flaɪzə fæst]) or inserted vowel-initial word following the verb (4 tokens) (e.g., *He throws fast* [hi θɹoʊz ɪt fæst]) were excluded from the analysis to avoid issues of possible re-syllabification. This was primarily an issue for Participant 7 (see Table 7), where all eight medial forms were produced with an epenthetic vowel or inserted vowel-initial word. Some children occasionally deleted the final word in a medial target sentence, producing a 2-word utterance with the verb in final position (e.g., *He sleeps now* [hi slips]). These were also excluded from the analysis (17 tokens). The resulting dataset included 147 tokens in simple C contexts and 158 tokens in complex CC contexts. The number of 3rd person singular morphemes produced out of the total attempted sentences for each participant is summarized in Table 7.

[insert Table 7 about here]

Results

Figure 1 shows the average percent correct production of 3rd person singular morphemes as a function of both phonological complexity and position within the utterance. Overall, in utterance-medial position, children produced 3rd person singular -*s* more often in simple C (*Mean* = 60.1%, *SE* = 8.5) compared to complex CC context (*Mean* = 51.4%, *SE* = 8.7); similarly, in utterance-final position, children produced 3rd person singular -*s* more often in simple C (*Mean* = 75.7%, *SE* = 4.7) compared to complex CC context (*Mean* = 63.8%, *SE* = 7.7).

[insert Figure 1 about here]

To test for the effects of complexity and position, we performed a repeated-measures ANOVA with coda complexity (simple, complex) and utterance position (medial, final) as the within-subjects variables, and percent -*s produced* as the dependent variable. Because we were testing the significance of *a priori*, directional predictions about the effects of complexity and position, one-tailed tests were more appropriate than the more typical, two-tailed tests. The main effect of complexity was significant, $F(1,22) = 3.3$, $p = 0.04$, $\eta_p^2 = 0.13$; and the main effect of position was also significant, $F(1,22) = 3.07$, $p = 0.04$, $\eta_p^2 = 0.15$. The interaction between complexity and position was not significant, $F(1,22) = 0.11$, $p = 0.37$, $\eta_p^2 = 0.01$. Thus, consistent with our predictions, children produced 3rd person singular -*s* more often in simple C than in complex CC context. Children also produced -*s* more often utterance-finally compared to utterance-medially. This replicates the findings of the longitudinal study, where the effects of coda complexity and utterance position on the production of 3rd person singular morpheme production were found to be independent.

Further analysis showed that, unsurprisingly, these children's CDI scores (see Table 7) were positively correlated with their production accuracy of the 3rd person singular morpheme, $r = 0.5$, $p = 0.02$. In typically developing children it is quite possible that the correlation between vocabulary and production accuracy is mediated by age. In other words, perhaps both CDI scores and production accuracy correlate with age, and thus, are correlated with each other. However, this was not the case. Specifically, although age (in days) was significantly correlated with CDI scores, $r = 0.46$, $p = 0.03$, there was no significant correlation between age and production accuracy, $r = 0.28$, $p = 0.20$. Finally, we partialled out the effect of age and re-calculated the correlation between CDI scores and production accuracy. The partial correlation between CDI scores and production accuracy, controlling for age, was still significant, $r = 0.44$, $p = 0.04$. Thus, even older children with small vocabularies showed poor grammatical performance.

Together with the results on MLU in the longitudinal study, these significant partial correlations provide evidence for a strong link between children's overall morphological/lexical development and their production of the 3rd person singular morpheme. These findings are also broadly in accordance with studies showing that children's vocabulary size mediates the frequency effects on their production accuracy (Edwards, Beckman, & Munson, 2004; Munson, Kurtz, & Windsor, 2005). To conclude, the results from both the longitudinal study and the cross-sectional study show that young children are more likely to produce 3rd person singular morphemes in phonologically simple, or unmarked contexts, especially in utterance-final position.

General Discussion

The goal of the present study was to determine if some of the variability in typically developing English-speaking children's production of 3rd person singular *-s* could be explained by phonological factors. If so, it would provide a principled explanation for some of the variable production of this morpheme, indicating that it was phonologically conditioned and not simply random. It would also indicate that children's syntactic competence might be more robust than often assumed.

In the longitudinal study we demonstrated that children produced 3rd person singular *-s* more accurately in phonologically simple C coda contexts than in complex CC coda contexts. There was also an effect of position within the utterance, with worse performance in utterance-medial position. Utterance-medial syllables are typically shorter in duration, rendering less time for children to produce segments. The findings in the longitudinal study also showed that the utterance length and the child's MLU significantly contributed to explaining the early production of 3rd person singular *-s*.

We confirmed these findings in the cross-sectional study with 2-year-olds, where utterance length and inflected frequency were held constant. Thus, our findings provide strong support for the role of phonological constraints at the level of both the syllable and the utterance in explaining some of the variability in young children's production of 3rd person singular *-s*. That is, at early stages of acquisition, children are more likely produce 3rd person singular *-s* in phonologically simple contexts. This is consistent with the Prosodic Licensing Hypothesis that young children will first produce grammatical morphemes in phonologically (or prosodically) simple, unmarked contexts (Demuth & McCullough, in press).

The fact that children show better command of 3rd person singular morphemes in phonologically simple contexts also suggests that they may have access to some of the syntax and semantics of these constructions earlier than is often assumed. Further support for this position comes from perception/comprehension experiments showing that children have an awareness of several grammatical morphemes well before they can reliably produce them. Early in the second year of life children are sensitive to grammatical morphemes, as evidenced by 13-month-olds' detection of phonetic changes that convert function words into nonsense words (Shi, Werker & Cutler, 2006). Gerken, Landau, and Remez (1990) also noted that children below the age of 2 who do not yet produce articles notice when the article *the* is changed to a nonce word. Particularly relevant to this study, Soderstrom, Wexler, and Jusczyk (2002) report that 19-month-olds prefer to listen to grammatical passages with 3rd person singular -*s* over ungrammatical passages without it (e.g., *At the bakery, a team bakes bread* vs. **At the bakery, a team bake bread*), demonstrating their sensitivity to the grammatical distribution of the 3rd person singular morpheme (see also Soderstrom, White, Conwell, & Morgan, 2007). Preliminary findings from the perception experiment with the participants in the present cross-sectional study indicate that children as young as 22 months are sensitive to grammatical/ungrammatical contrasts with 3rd person singular -*s* in a referential task (Sundara et al., in preparation). Together, these findings indicate that children have some early awareness of grammatical agreement, raising the possibility that the grammatical representation of at least person and number, if not 'tense', are emerging quite early in development.

In addition to coda complexity effects, the longitudinal and cross-sectional studies also showed that children are more likely to produce 3rd person singular -*s* in utterance-final compared to utterance-medial position. Morphemes like the 3rd person singular are lengthened at the ends of utterances in the parental input children hear (Hsieh et al., 1999), making it more likely that children will detect them in this position. Snow (1994, 1998) further shows that children's own productions begin to exhibit longer duration at phrasal boundaries around the time they begin to produce word combinations. Thus, it is likely that children have more time to produce coda consonants and morphemes phrase-finally as compared to phrase-medially. From an articulatory/planning perspective, 3rd person singular *-s* might also be more challenging in utterance-medial position due to the fact that another word follows, necessitating the planning of additional articulatory gestures. In contrast, at the end of an utterance, especially in slower child speech, no additional gestural planning is immediately required. Finally, the ends of utterances have the advantage of being the most recent in memory, perhaps facilitating production in elicited imitations tasks. Further acoustic investigation of children's speech timing and realization of 3rd person singular *-s* in these different phrasal contexts would provide some insight into which of the above factors is most important for explaining these behavioral findings.

Aside from the effects of syllable complexity and utterance position, MLU and utterance length also had the expected effect on production accuracy. Children with larger MLUs were more likely to accurately produce 3rd person singular *-s,* especially in shorter utterances. Children in the cross-sectional study with larger vocabularies (measured by CDI scores) also produced the 3rd person singular morpheme more accurately, suggesting a close connection between lexical and morphological development. Surprisingly, however, the inflected frequency of the verb was not correlated with production variability in the longitudinal study, contra findings on the production of plural morphemes (Zapf, 2004). It is possible that the frequency statistics reported for the inflected frequency of 3rd person singular verbs in the CHILDES database did not constitute an appropriate model of inflected-frequency for the individual children in the longitudinal study. Alternatively, it is possible that some other measure of frequency, such as phonotactic probability of consonant clusters, would better account for some of the variability in 3rd person singular morpheme production (e.g., Munson, 2001; Storkel, 2001; Maekawa & Storkel, 2006).

One might wonder if all inflectional morphemes are susceptible to coda complexity to the same extent. We assessed the spontaneous production of three of the children in the longitudinal study (Ethan, Naima, William) for complexity effects on the production of plural *-s*. The results showed no effects of coda complexity, indicating that these children can produce plural *-s* equally well in both simple and complex codas. However, many of these pluralized nouns occurred phrase-finally in short utterances (e.g., *Two cats!*). The plural nouns in general, and those with complex codas (e.g., *books, dogs, cars*), were also much more frequent compared to 3rd person singular verbs. This suggests that a combination of plural token frequency and complexity, as well as a tendency for plurals to occur finally in short utterances, may reduce the effects of phonological complexity on children's production of plural *-s*, facilitating earlier production. On the other hand, 3rd person singular *-s* might be more likely to be affected by coda complexity as they tend to occur utterance-medially and are overall less frequent than plural *-s* (Hsieh et al., 1999).

The results from this study raise many other questions about the phonology of children's early 3rd person singular morphemes. For example, little is known about the acoustics of this morpheme, in either child or parental speech. If 3rd person singular *-s* exhibits shorter duration in utterance-medial position in child-directed speech, perhaps young children also produce it with short duration, rendering it inaudible to the adult transcriber (Scobbie, Gibbon, Hardcastle, &

Fletcher, 2000). It would therefore be interesting to investigate the possibility of covert phonetic contrasts on children's apparent omission of 3rd person singular -*s*. This suggests that further acoustic analysis, both of the input children hear (cf. Newman, Clouse, & Burnham, 2001), and of child productions, would provide further evidence of this morpheme in children's underlying phonological representations.

Further acoustic analysis could also address possible issues of re-syllabification across word boundaries. In a preliminary analysis we found that two of the children in the longitudinal study appeared to preserve 3rd person singular -*s* at higher rates when the verb was followed by a word beginning with a vowel. However, it is not clear if this is most likely when the following word is an unstressed grammatical morpheme (e.g., *in, up*), or if this is a more general process that occurs even with a word that begins with a sonorant onset (e.g., *needs led* > *need sled*). There are other phonological environments, including the segmental and sonority content of the stem (cf. Oetting & Horohov, 1997; Johnson & Morris, 2007), that might also facilitate the production of 3rd person singular morphemes, and this could be investigated using acoustic analysis as well.

Finally, researchers have found a close connection between the semantics of the verb (e.g., accomplishment vs. activity, punctual vs. durative) and children's use of the past tense morpheme (e.g., Bloom, Lifter & Hafitz, 1980; Johnson & Morris, 2007). Studies have also shown that semantic complexity is a factor affecting speech processing (Gennari & Poeppel, 2003). It would therefore be interesting to explore the possible contribution of semantics to understanding some of the variable production of 3rd person singular -*s* (cf. Hyams, 2007).

The findings from this study point to the fact that phonological factors account for much of the variability in children's early production of 3rd person singular -*s*. Children are more likely to produce this morpheme in phonologically simple contexts, i.e., in simple codas utterance-finally. In contrast, they are more likely to omit this morpheme in phonologically more complex contexts, i.e., in complex coda clusters utterance-medially. These findings hold important methodological and theoretical implications for the field of language acquisition. First, they point to the need for syntactic and semantic experiments to control for issues of phonological complexity; only then can we better understand the true nature of children's morphological or syntactic competence. Second, they suggest that children's syntactic representations may emerge much earlier than typically assumed. If children can produce 3rd person morphemes in prosodically (or phonologically) licensed (simple, unmarked) contexts, this suggests that they have some of the requisite knowledge of grammar. Future research will be required to develop a more complete developmental model of planning and production, where the contributions of phonological complexity, as well as the other issues outlined above, all play a role in our understanding of how and why children's early utterances take the variable form they do.

Conclusion

The goal of this study was to examine the effects of phonology on young children's variable production of English 3rd person singular -*s*. To do this, we examined the possible effects of both coda complexity and position of the 3rd person singular verb within the utterance. We first investigated the development of 3rd person singular morphemes in longitudinal speech data from 6 children between the ages of 1;3-3;6. We then addressed the same issue by testing 23 2-year-olds in a cross-sectional, elicited imitation experiment. The results from both studies showed that children were better at producing 3rd person singular -*s* in simple coda contexts compared with complex consonant cluster codas, and in utterance-final as compared to utterance-medial position, providing further support for the hypothesis that children's early grammatical morphemes are prosodically licensed. This suggests that future research on morphological development will need to consider phonological complexity and positional effects in constructing a comprehensive theory of how and when grammatical morphemes are acquired.

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Appendix A

Types and tokens analyzed for each child in simple C contexts

	Alex		Ethan		Lily		Naima		Violet		William	
C	*cries*	1	*flies*	1	*blows*	1	*cries*	1	*goes*	38	*blows*	1
	goes	71	*glows*	5	*flies*	1	*goes*	34	*grows*	1	*goes*	15
	says	12	*goes*	8	*goes*	41	*knows*	3	*plays*	2	*plays*	1
			grows	2	*plays*	1	*plays*	1	*says*	24	*says*	3
			knows	2	*says*	22	*says*	21			*sees*	1
			plays	1	*sees*	2	*tries*	1				
			says	4								
			sees	1								
Total		84		24		68		61		65		21

Appendix B

Types and tokens analyzed for each child in complex CC context

	Alex		Ethan		Lily		Naima		Violet		William	
CC	*comes*	3	*clacks*	1	*comes*	5	*comes*	3	*comes*	2	*bites*	2
	drives	2	*comes*	2	*dings*	1	*eats*	8	*fits*	4	*breaks*	1
	eats	1	*cuts*	2	*eats*	1	*fits*	1	*gets*	1	*comes*	12
	fits	2	*digs*	2	*gets*	1	*gets*	1	*hops*	1	*eats*	1
	gets	1	*eats*	4	*likes*	2	*looks*	6	*likes*	6	*fits*	1
	looks	4	*gets*	1	*lives*	3	*makes*	1	*looks*	24	*gets*	1
	means	2	*hooks*	1	*looks*	11	*needs*	21	*loves*	2	*hates*	1
	needs	4	*keeps*	1	*loves*	4	*sings*	3	*makes*	1	*hits*	2
	sings	1	*likes*	1	*makes*	3	*sits*	1	*means*	1	*likes*	1
	sits	1	*looks*	30	*means*	6	*sounds*	2	*moves*	1	*looks*	1
	sleeps	1	*makes*	3	*needs*	9	*stands*	4	*needs*	4	*needs*	1
	sounds	1	*means*	3	*rocks*	1	*tucks*	1	*sticks*	2	*rings*	3
			needs	4	*sings*	3	*walks*	1	*stops*	1	*runs*	2
			rides	5	*sits*	1			*walks*	6	*scoops*	2
			sleeps	1	*sleeps*	2					*sounds*	4
			sounds	1	*sounds*	1						
					sticks	1						
					swims	1						
Total		23		62		56		53		55		35

Author Note

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Table 1

Gender, age and MLU profiles of participants.

Participants	Gender	Age at first recording	Age range studied	MLU range
Alex	Male	1;4.28	2;5.9 – 3;5.16	2.18 – 3.15
Ethan	Male	0;11.4	1;3.15 – 2;6.25	1.52 – 3.65
Lily	Female	1;1.2	1;9.12 – 2;7.1	1.84 – 3.99
Naima	Female	0;11.28	1;5.11 – 2;5.29	2.34 – 4.37
Violet	Female	1;2.0	1;9.25 – 3;6.21	1.59 – 3.65
William	Male	1;4.10	1;10.10 – 3;4.15	1.56 – 3.32

Table 2

Number of tokens coded as '-s produced' vs. '-s missing' in C and CC contexts.

	C context (e.g., goes [goz])			*CC context (e.g., looks [lʊks])*						
	-s produced	*-s missing*		*-s produced*				*-s missing*		
	[goz]	*[go]*	*[gop]*	*[lʊs]*	*[lʊks]*	*[lʊts]*	*[luksk]* *[lukps]*	*[lʊk]*	*[lʊp]*	*[lʊ]*
Alex	59	25	-	7	3			8		5
Ethan	18	6	-	3	15			29	1	14
Lily	56	12	-	2	42		1	10		1
Naima	53	7	1	5	29		1	17		1
Violet	45	20	-	4	22	2		17	1	9
William	12	9	-	2	14	2		9	2	6
Total	243	79	1	23	125	4	2	90	4	36

Table 3

Number (percent) of children's production of 3rd person singular -s in C and CC contexts over time.

Age	*Alex*		*Ethan*		*Lily*	
	C	CC	C	CC	C	CC
1;3-1;6	-	-	4/6 (67%)	0/9 (0%)	-	-
1;7-1;10	-	-	6/8 (75%)	3/23 (13%)	-	0/1 (0%)
1;11- 2;2	-	-	4/5 (80%)	8/20 (40%)	16/22 (73%)	13/23 (57%)
2;3-2;6	1/16 (6%)	-	4/5 (80%)	7/10 (70%)	35/41 (85%)	31/31 (100%)
2;7-2;10	3/9 (33%)	3/9 (33%)	-	-	5/5 (100%)	1/1 (100%)
2;11-3;2	51/52 (98%)	7/12 (58%)	-	-	-	-
3;3-3;6	4/7 (57%)	0/2 (0%)	-	-	-	-
Total	59/84 (70%)	10/23 (43%)	18/24 (75%)	18/62 (29%)	56/68 (82%)	45/56 (80%)

Age	*Naima*		*Violet*		*William*	
	C	CC	C	CC	C	CC
1;3-1;6	5/5 (100%)	-	-	-	-	-
1;7-1;10	26/30 (87%)	12/20 (60%)	5/7 (71%)	0/4 (0%)	0/2 (0%)	1/1 (100%)
1;11- 2;2	8/8 (100%)	8/14 (57%)	8/13 (62%)	3/6 (50%)	-	4/5 (80%)
2;3-2;6	14/18 (78%)	15/19 (79%)	21/29 (72%)	12/18 (67%)	1/1 (100%)	1/1 (100%)
2;7-2;10	-	-	8/13 (62%)	5/10 (50%)	3/4 (75%)	5/9 (56%)
2;11-3;2	-	-	1/1 (100%)	2/3 (67%)	6/11 (55%)	3/9 (33%)
3;3-3;6	-	-	2/2 (100%)	6/14 (43%)	2/3 (67%)	4/10 (40%)
Total	53/61 (87%)	35/53 (66%)	45/65 (69%)	28/55 (51%)	12/21 (57%)	18/35 (51%)

Table 4

Relative contribution of individual factors in explaining the production patterns of 3rd person singular -s using logistic regression. Negelkerke's R^2 was 0.07 for step 1; 0.12 for step 2; 0.13 for step 3; 0.14 for step 4; and 0.15 for step 5. Only significant ($p<0.05$) contributors are included at every step.

Factor	*Coefficient B*	*SE B*	*Wald*	*Exp (B)*	*p-value*
Step 1					
Complexity (C, CC)	-0.942	0.176	28.786	2.564	<0.001
Step 2					
Complexity (C, CC)	-1.046	0.182	33.189	0.351	<0.001
MLU	0.853	0.178	23.080	2.348	<0.001
Step 3					
Complexity (C, CC)	-1.014	0.183	30.784	0.363	<0.001
MLU	1.027	0.190	29.145	2.792	<0.001
Utterance Length	-0.101	0.036	7.914	0.904	0.005
Step 4					
Complexity (C, CC)	-1.018	0.184	30.699	0.361	<0.001
MLU	1.089	0.194	31.576	2.972	<0.001
Utterance Length	-0.080	0.037	4.677	0.923	0.031
Position (final, medial)	-0.483	0.220	4.822	0.617	0.028
Step 5					
Complexity (C, CC)	-1.038	0.185	31.543	0.354	<0.001
MLU	1.145	0.198	33.565	3.143	<0.001

Utterance Length	-0.153	0.052	8.735	0.858	0.003
Position (final, medial)	-1.223	0.436	7.875	0.294	0.005
Utterance Length*Position	0.199	0.099	4.020	1.221	0.045

Table 5

Characteristics of the target verbs used in the cross-sectional study.

	Proportion of children from CDI database			Frequency from CHILDES database	
Target verb	Comprehending at 16-months	Producing at 16-months	Producing at 24-months	Inflected	Non-inflected
Blow	58.3	9.7	54.2	24	545
Cry	63.9	19.4	67.3	38	296
Fly	Missing entry from CDI			39	305
Throw	77.8	9.7	48.6	24	858
Drive	36.1	4.2	54.2	39	292
Eat	84.7	19.4	79.4	135	3960
Run	50	5.6	56.1	59	618
Sleep	61.1	15.3	61.7	56	822

Table 6

Duration of 3rd person singular -s, and the preceding vowel in target sentences (in ms).

Coda complexity	Position	Sentence	Durations (ms)	
			3rd person singular -*s*	Preceding vowel
Simple	Medial	He blows now	99	445
		He cries now	97	368
		He flies fast	121	426
		He throws fast	134	249
	Final	Here he blows	205	706
		There he cries	200	570
		Here he flies	170	831
		There he throws	228	459
Complex	Medial	She drives fast	169	312
		She eats now	117	179
		He runs fast	118	197
		He sleeps now	146	144
	Final	Here she drives	175	446
		Here she eats	234	250
		There he runs	192	264
		There he sleeps	215	238

Table 7

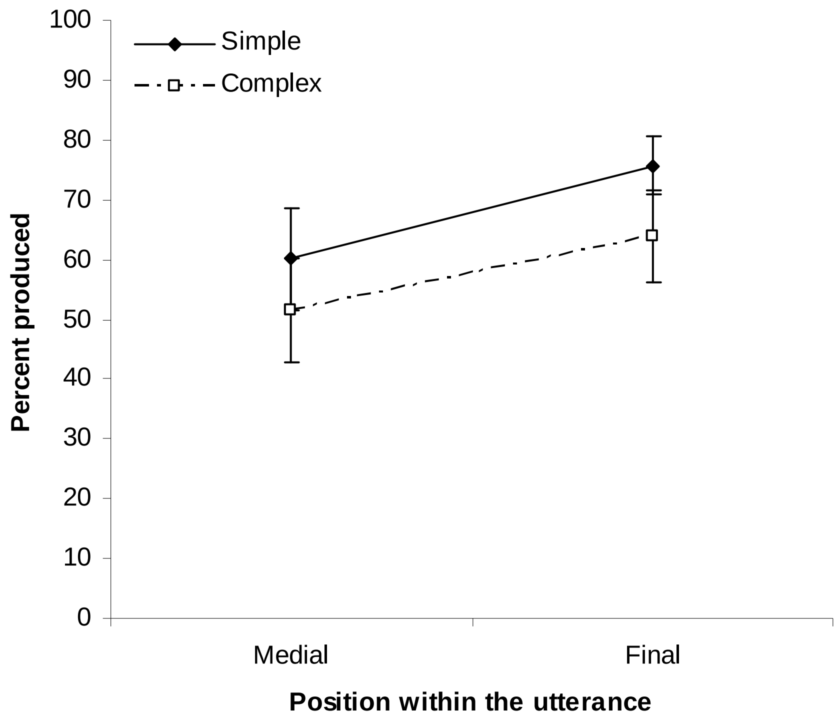
Number of tokens with -s produced out of total attempted tokens at each coda complexity and utterance position. Children with 0 correct productions and children at ceiling are excluded from the table.

Participant number	Age (year;month:days)	CDI Item Scores	Simple Medial Position	Simple Final Position	Complex Medial Position	Complex Final Position	**Total**
1	1;9:30	100	0/0	4/4	0/3	2/4	**6/11**
2	1;10:8	71	2/4	3/3	1/4	4/4	**10/15**
3	1;10:15	41	0/1	2/4	0/2	0/1	**2/8**
4	1;10:10	44	2/3	2/4	1/4	1/4	**6/15**
5	1;10:9	51	3/3	4/4	2/4	3/4	**12/15**
6	1;9:20	58	3/3	2/4	3/4	3/3	**11/14**
7	2;4:16	82	0/0	2/4	0/0	2/4	**4/8**
8	2;4:0	83	3/3	4/4	2/3	2/3	**11/13**
9	2;3:26	96	3/3	3/3	2/4	2/4	**10/14**
10	2;3:15	75	0/4	4/4	0/4	3/4	**7/16**
11	2;3:20	76	2/4	1/3	2/4	3/4	**8/15**
12	2;4:00	97	4/4	2/4	4/4	4/4	**14/16**
13	2;3:16	71	0/3	3/4	4/4	4/4	**11/15**
14	2;3:11	86	1/2	4/4	3/4	3/4	**11/14**
15	2;3:18	67	2/2	3/4	2/3	3/4	**10/13**
16	2;3:12	62	2/3	2/3	2/2	0/2	**6/10**

17	2;3:21	99	4/4	3/4	4/4	3/4	**14/16**
18	2;3:25	88	3/3	2/4	4/4	3/4	**12/15**
19	2;3:25	84	3/4	3/4	0/3	3/4	**9/15**
20	2;3:13	43	1/2	3/4	1/2	2/4	**7/12**
21	2;3:27	66	2/2	2/3	1/2	0/3	**5/10**
22	2;3:15	99	0/0	3/3	1/2	3/4	**7/9**
23	2;3:15	81	3/4	4/4	2/4	4/4	**13/16**
Total			**43/61**	**65/86**	**41/74**	**57/84**	**206/305**

Figure captions

Figure 1. Percent production (± *SE*) for simple and complex codas in utterance-medial and final positions by 2-year-olds (n = 23)


100
90
80
70
60
50
40
30
20
10
0
Simple
Complex
Percent produced
Medial
Final
Position within the utterance