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Research Note

Examination of the Locus of Positional Effects on Children's Production of Plural –*s*: Considerations From Local and Global Speech Planning

Rachel M. Theodore,[a] Katherine Demuth,[b,c] and Stefanie Shattuck-Hufnagel[d]

Purpose: Prosodic and articulatory factors influence children's production of inflectional morphemes. For example, plural –*s* is produced more reliably in utterance-final compared to utterance-medial position (i.e., the positional effect), which has been attributed to the increased planning time in utterance-final position. In previous investigations of plural –*s*, utterance-medial plurals were followed by a stop consonant (e.g., *dogs bark*), inducing high articulatory complexity. We examined whether the positional effect would be observed if the utterance-medial context were simplified to a following vowel.
Method: An elicited imitation task was used to collect productions of plural nouns from 2-year-old children. Nouns were elicited utterance-medially and utterance-finally, with the medial plural followed by either a stressed or an unstressed vowel. Acoustic analysis was used to identify evidence of morpheme production.
Results: The positional effect was absent when the morpheme was followed by a vowel (e.g., *dogs eat*). However, it returned when the vowel-initial word contained 2 syllables (e.g., *dogs arrive*), suggesting that the increased processing load in the latter condition negated the facilitative effect of the easy articulatory context.
Conclusions: Children's productions of grammatical morphemes reflect a rich interaction between emerging levels of linguistic competence, raising considerations for diagnosis and rehabilitation of language disorders.

Language acquisition entails development of multiple levels of linguistic representation, including sound structure, lexical knowledge, and syntactic knowledge. Children perceive distinctions between contrastive phonemes prior to acquiring the fine-grained articulatory control required to produce such distinctions. Children's lexicons begin to develop long before they have acquired an adultlike sound structure, and syntactic knowledge is observed in children's productions even at an age where lexical knowledge will continue to grow for many years.

[a]University of Connecticut, Storrs
[b]Macquarie University, North Ryde, New South Wales, Sydney, Australia
[c]Santa Fe Institute, New Mexico
[d]Speech Communication Group, Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge

Correspondence to Rachel M. Theodore: rachel.theodore@uconn.edu

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Thus, language acquisition is a process in which the different aspects of language are simultaneously being developed, refined, and linked together over time.

Given this developmental feat, it is perhaps not surprising that children's early productions are notoriously variable (e.g., Bloom, 1970). The current work considers this issue, focusing on variability in the production of grammatical morphemes that are inflected on lexical forms, such as plural –*s*. There is a growing body of literature indicating that variability in morpheme production is systematically related to semantic, phonological, articulatory, and higher-level planning factors. Consider the contribution of semantic knowledge: The plural morpheme is more often produced when children are asked to label a set of objects that are highly similar in appearance versus a set of objects that are very distinct (Zapf & Smith, 2008). In terms of phonology, grammatical morphemes are produced more reliably in contexts that form a simple coda (e.g., *flies*) versus a cluster coda (e.g., *drives*; Song, Sundara, & Demuth, 2009).

Studies investigating the variable production of articles have shown that 2-year-old children are more likely to produce an article when it can form a disyllabic trochaic

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foot with the preceding stressed monosyllabic item (e.g., *I [WANT the] bread*) compared to when it is preceded by a word that already forms a trochaic foot (e.g., *I'm [CATCHing] [the] pig*; Demuth & McCullough, 2009; Gerken, 1996). These findings suggest that a following unstressed vowel (e.g., My *[DOGS a][rrive]*) may provide a better context for resyllabification of the plural morpheme than a following stressed vowel (e.g., *My [DOGS] [eat]*), which may enhance morpheme production. However, morpheme production is also influenced by utterance length, which suggests that more general cognitive influences, such as working memory, may also interact with grammatical knowledge during online speech production (e.g., Song et al., 2009). Such findings extend the traditional view of variability in the production of grammatical morphemes as being the consequence of impoverished syntactic representations to highlight interactions between other emerging levels of linguistic processing. Indeed, further support for this idea comes from Mealings and Demuth (2014), who examined the effects of utterance position and utterance length (three- vs. five-word utterances) on production of third-person singular *–s* in 3-year-old children. They observed a striking interaction between these two factors in that the effect of utterance position was found only for the five-word utterances, suggesting that the omission of inflectional morphemes by 3-year-old children reflects the confluence of difficulty created by challenging articulatory planning for morphemes in utterance-medial position combined with the increased processing load of five-word utterances. Thus, it appears that local within-word articulatory planning factors and global higher-level sentence planning factors are both involved in children's emerging abilities to produce their intended utterances.

Our earlier findings have shown that global planning factors, including utterance position, influence children's early productions of plural *–s* (Theodore, Demuth, & Shattuck-Hufnagel, 2011). We used an imitation task to elicit productions of plural nouns in two types of three-syllable phrases, one where the noun occurred utterance-medially (e.g., *The dogs bark*) and one where the noun occurred utterance-finally (e.g., *See the dogs*). The results showed that more morphemes were produced in utterance-final compared to utterance-medial position. This effect may be the consequence of the utterance-final segments being more likely to be produced due to the phonological process of phrase-final lengthening. We posited that plural *–s* production was "easier" in utterance-final position because in this position there is more time to translate phonological representations into articulatory gestures. Indeed, theoretical models of speech production posit that productive morphology reflects the output of a cascading system of activation as the speaker moves from a conceptual representation to articulation (e.g., Dell, 1986; Levelt, Roelofs, & Meyer, 1999). Within these frameworks, utterance position can be viewed as a global influence on speech production in which there is additional time to plan articulatory gestures for sounds produced at the ends of utterances compared to those produced earlier in the utterance.

In Theodore et al. (2011), we attributed the effect of utterance position on morpheme production, at least in part, to the difference in planning time, given that the same nouns were elicited in both medial and final utterance positions (thus controlling for conceptual and phonological factors). We also controlled the medial context so that the morpheme was always followed with a stop consonant (e.g., *My dogs barked*). This context thus required a complex series of articulatory gestures where the child must create a very narrow occlusion for the fricative realization of the morpheme and follow that gesture with a brief period of complete occlusion prior to releasing the following stop consonant. Perhaps the locus of the positional effect is not planning time, but rather an interaction between the global factor of planning time and other factors such as local articulatory difficulty. Given the host of findings demonstrating utterance position effects on morpheme production, a more fine-grained analysis of the locus of this effect is needed to move toward a model of speech planning and production that accurately characterizes the developmental trajectory.

The goal of the current work was therefore to examine the locus of the positional effect. Here we consider two potential loci: *local* planning influences defined as the articulatory context in which the morpheme occurs, and *global* planning influences defined as factors that operate above the level of a local segmental context including speech planning time and utterance length. In two experiments, we used the same imitation paradigm to elicit productions of plural nouns in utterance-medial and utterance-final positions, half with simple codas and the other half with complex codas. In Experiment 1, the utterance-medial contexts were constructed such that the plural was always followed by a stressed vowel (e.g., *The dogs eat*). Producing a vowel following the plural requires a simpler set of articulatory gestures and thus provides an "easier" articulatory context compared to our earlier work, where the following word began with a consonant. The utterance-final contexts were identical to those used in Theodore et al. (2011; e.g., *Touch the dogs*). In Experiment 2, the utterance-medial contexts consisted of a plural followed by an unstressed vowel (e.g., *The dogs arrive*) and the same utterance-final contexts as Experiment 1. Thus, the local articulatory context in utterance-medial position was identical in both experiments (a vowel) and different from that previously examined (a stop consonant). However, the processing load for the utterance-medial stimuli in Experiment 2 was increased compared to Experiment 1 due to the lower frequency lexical items, a lower frequency iambic stress pattern, as well as the addition of an extra, pretonic syllable (e.g., *eat* vs. *arrive*), all of which may be considered global influences on speech production (e.g., Levelt & Wheeldon, 1994).

If the global influence of speech planning time is the primary factor driving positional effects in children's early speech, as we concluded in Theodore et al. (2011), then the positional effect will emerge in both experiments such that more morphemes are produced in utterance-final compared to utterance-medial position, even though we have simplified the local articulatory context. Alternatively, if the local planning factor of articulatory context is the putative variable, then the positional effect will not emerge in either experiment, given the relatively simple articulatory gestures of the medial contexts. The third prediction is that if local articulatory context interacts with speech planning time and other cognitive factors such as syllable length and lexical frequency, as predicted by Mealings and Demuth (2014), then the positional effect should emerge only in Experiment 2, where global planning factors lead to the greatest processing load for the utterance-medial tokens.

Experiment 1

Method

Participants. Fourteen full-term 2-year-olds from the Providence, Rhode Island, community participated in the experiment. The children (eight girls, six boys) ranged in age from 26 to 30 months (M = 28 months). The participants were from monolingual English-speaking homes, were healthy on the day of testing, and had typically developing speech and language skills according to parental report. Percentile scores for vocabulary size using the MacArthur-Bates Communicative Development Inventories (CDI; Fenson et al., 2000) ranged from 5 to 99 (M = 64, SD = 34). Eleven additional children were excluded from the analyses: Five did not talk, and six failed to meet the criterion for inclusion (repeating at least 12 of the 16 experimental prompts total, including two in each of the four cells created by crossing the independent variables).

Stimuli. The stimuli consisted of the same eight target plural nouns used in Theodore et al. (2011). Half of the items contained a simple coda (e.g., *cows*), and the other half contained a cluster coda (e.g., *dogs*). For the targets with a cluster coda, the final segment of the uninflected form was always a voiced stop; accordingly, plural *–s* for both simple and cluster targets phonologically manifested as /z/. As shown in Table 1, each target noun was placed in two sentences, one where the noun occurred utterance-finally (e.g., *Touch my dogs*), and one where the noun occurred utterance-medially (e.g., *My dogs eat*). The utterance-medial sentences were constructed such that they contained three syllables and the target noun was always followed by a stressed vowel. The utterance-final sentences were constructed such that they also contained three syllables, with the target noun appearing in final position.

To create the prompts for the elicited imitation task, a female native speaker of American English was recorded producing the 16 sentences. All recordings took place in a sound-attenuated booth, and speech was recorded directly to computer via a microphone connected to a pre-amplifier (44.1-kHz sampling rate, 16-bit quantization). Praat software (Boersma & Weenink, 2010) was used to excise each sentence from the sound file of the recording session and to measure sentence duration, target noun duration, and morpheme duration for each token. Following criteria outlined in Theodore et al. (2011), sentence duration was measured from the onset to offset of vocal energy in the utterance; duration of the target noun was measured from the onset of closure duration associated with the initial stop consonant to the offset of aperiodic acoustic energy associated with the plural *–s*; and duration of the plural *–s* proper was measured from the onset and offset of high-frequency, aperiodic noise associated with fricative production. Each duration type was submitted to analysis of variance (ANOVA) with Utterance Position (medial vs. final) and Coda Complexity (simple vs. cluster) as factors. In terms of sentence duration, there was no main effect of utterance position, $F(1, 6) = 0.52$, $p = .496$, no main effect of complexity, $F(1, 6) = 0.36$, $p = .570$, and no interaction between the two, $F(1, 6) = 3.09$, $p = .129$, indicating that the duration of the sentences was approximately equal for both variables manipulated in the present experiment. For duration of the target noun, there was a main effect of position as expected, $F(1, 6) = 58.12$, $p < .001$, with duration of the target noun longer in utterance-final compared to utterance-medial position. There was no main effect of coda complexity, $F(1, 6) = 0.05$, $p = .833$, and no interaction between utterance position and coda complexity, $F(1, 6) = 1.91$, $p = .216$. In terms of morpheme duration, we again observed the expected main effect of utterance position, $F(1, 6) = 37.72$, $p < .001$, with morphemes in final position longer compared to utterance-medial position.

Table 1. Stimulus sentences used in Experiments 1 and 2 to elicit the simple and cluster coda targets in utterance-medial and utterance-final positions.

		Utterance position		
		Medial		Final
Coda	Target	Experiment 1	Experiment 2	Experiments 1 and 2
Simple	*cows*	My cows eat.	My cows arrive.	See my cows.
	bees	His bees eat.	His bees appear.	Hear his bees.
	boys	Her boys ask.	Her boys arrive.	See her boys.
	pies	My pies ooze.	My pies appear.	Taste my pies.
Cluster	*dogs*	My dogs eat.	My dogs arrive.	Touch my dogs.
	pigs	His pigs eat.	His pigs appear.	Hear his pigs.
	heads	Their heads ache.	Their heads appear.	See their heads.
	bags	Her bags ooze.	Her bags arrive.	See her bags.

There was no effect of coda complexity, $F(1, 6) = 0.26$, $p = .627$, and no interaction between utterance position and coda complexity, $F(1, 6) = 0.08$, $p = .794$. These results confirm that the duration characteristics of the auditory prompts are equivalent to those used in Theodore et al. (2011) and thus promote more direct comparisons of the results here and in the earlier study, despite having unique stimuli between the two.

Procedure. As in our earlier study (Theodore et al., 2011), each child was invited into a sound-attenuated room with a parent to "play a game." The child was seated at a table in front of a computer monitor and a pair of speakers. The room contained two lavalier microphones (Audio-Technica 700 Series, Tokyo, Japan) that were connected to a computer in an adjoining room via the MBox 2 Audio Interface (Digidesign [now Avid Audio], Daly City, CA). Microphone placement was determined on a child-by-child basis, depending on whether the child would wear one on his or her collar and taking a child's mobility throughout the experiment into account. The child was oriented to the task in a warm-up period in which he or she was asked to repeat what the computer said. Once the child was familiar with the task, he or she was directed to face the computer in order for the game to begin. Each trial consisted of a simultaneous presentation of the target noun (on the monitor) and the auditory prompt (via the speakers). The visual stimuli for the target nouns consisted of real-life photos with minimal background in each image and were acquired from a stock photo database. The authors and their research assistants informally judged the set of images to be equivalent across all nouns with respect to size of the target noun, figure–ground relationships within each photo, and the degree to which it would be engaging to children. The order of presentation was randomly determined for each child. Children were given the opportunity to hear each prompt up to three times. Note that successive prompts were provided only if the child did not attempt vocalization of the prompt and thus did not lead to practice effects. Formal data on the number of attempts for each trial were not collected, but we informally report that repeated prompts were rare overall and occurred most often as a means of promoting returned engagement to the task (e.g., the child had become distracted by the acoustical foam in the sound booth). General praise and stickers were provided in order to reward participation. After the experiment, the parent completed a brief demographic survey and the short form of the MacArthur-Bates Communicative Developmental Inventories (CDI; Fenson et al., 2000). The entire procedure lasted approximately 30 min.

Acoustic analysis. Each utterance was excised and saved to an individual file. Acoustic analysis was used instead of traditional listening protocols in light of findings indicating that children often produce systematic acoustic cues to feature contrasts that are not detected by adult listeners (see Munson, Edwards, Schellinger, Beckman, & Meyer, 2010, for a comprehensive review of this issue). Using Praat software, we analyzed each utterance for evidence of plural *–s* production using the criteria outlined in Theodore, Demuth, and Shattuck-Hufnagel (2012). To summarize, visual inspection of the waveform and spectrogram (along with experimenter listening) was used to identify the presence or absence of high frequency, aperiodic noise in the target noun following periodicity for the vowel or following closure for the stop consonant. The presence of this acoustic cue was then used as evidence of plural production, which is tightly linked to traditional perceptual metrics (Theodore et al., 2012). One trained coder conducted all acoustic measurements and a second trained coder remeasured 25% of the utterances; reliability between the two coders in terms of presence or absence of the morpheme was 94%. The few cases of disagreement were resolved by using the marks from the first coder.

Results

Mean morpheme production was calculated for each child for both simple and cluster codas for each utterance position by collapsing across the four tokens of each type and is shown in the left panel of Figure 1. These data were submitted to repeated-measures ANOVA with Coda Complexity and Utterance Position as factors. The results showed a greater proportion of produced morphemes in targets with simple codas ($M = 69\%$, $SD = 28$) compared to targets with complex codas ($M = 53\%$, $SD = 34$), $F(1, 13) = 9.09$, $p = .010$; $\eta^2 = .389$. However, the results showed no effect of utterance position, $F(1, 13) = 0.50$, $p = .494$; $\eta^2 = .068$, indicating that morpheme production was equally robust in utterance-medial ($M = 58\%$, $SD = 38$) compared to utterance-final contexts ($M = 65\%$, $SD = 30$). Moreover, there was no significant interaction between coda complexity and utterance position, $F(1, 13) = 0.38$, $p = .546$; $\eta^2 = .016$.

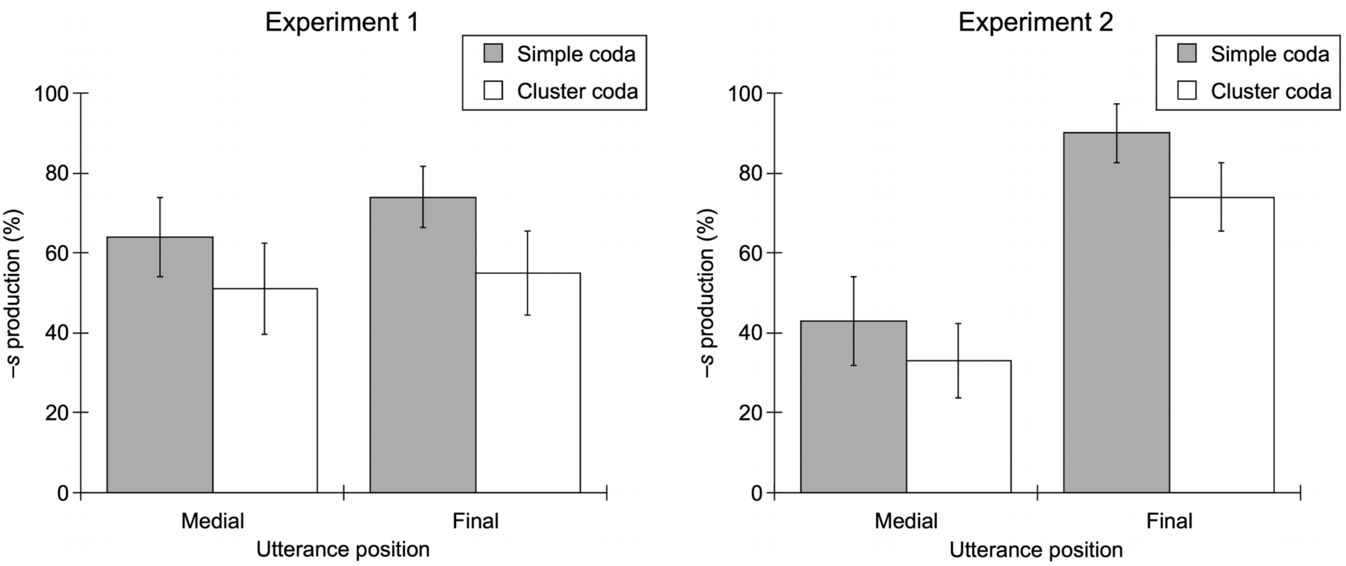
Experiment 2

Method

Participants. A different group of 14 full-term 2-year-olds were recruited from the Providence, Rhode Island, community for participation in Experiment 2. The children (six girls, eight boys) ranged in age from 25 to 30 months ($M = 28$ months). As in Experiment 1, they were from monolingual English-speaking homes, were healthy on the day of testing, and had typically developing speech and language skills according to parental report. Percentile scores for vocabulary size using the MacArthur CDI ranged from 15 to 99 ($M = 75$, $SD = 22$).[1] Thirty-one additional children

[1]Three independent *t* tests were conducted in order to compare participant characteristics among the children tested in Experiments 1 and 2. The participants in the experiments did not differ in age, $t(26) = 0.66$, $p = .51$; raw CDI score, $t(26) = -0.62$, $p = .54$; or percentile CDI score, $t(26) = 1.01$, $p = .32$. These analyses confirm that the general age and vocabulary size were comparable across the two experiments, and thus rule out the possibility that different patterns of performance reflect either age or CDI differences between the two groups.

Figure 1. Mean percent plural –*s* production in utterance-medial and utterance-final position for simple and cluster coda targets. The left panel shows results for Experiment 1, and the right panel shows results for Experiment 2. Error bars indicate standard error of the mean.



participated in the experiment but were excluded from the analyses for the following reasons: Thirteen did not talk, six failed to meet the criterion for inclusion (i.e., produce at least 12 of the 16 prompts), and 12 reduced the four-syllable utterance-medial sentence to three syllables by deleting the initial unstressed syllable of the final word (e.g., [əɹaɪv] to [ɹaɪv]), thereby omitting the critical vowel context of interest, as is common in children of this age (Demuth, 1996).

Stimuli. As shown in Table 1, the same eight target nouns used in Experiment 1 were also used in Experiment 2. The utterance-final sentences were the same as used in Experiment 1. The utterance-medial sentences were constructed so that the target plural was now followed by an unstressed vowel (e.g., *My* *dogs* *arrive*). Accordingly, the local articulatory context is vocalic (rather than consonantal) as for Experiment 1, and by the local planning hypothesis should again enhance morpheme production. However, the global planning difficulty is now increased, as the medial utterance contains four syllables rather than three. Given previous findings regarding the effects of increased utterance length (Mealings & Demuth, 2014), we predicted that this might induce lower morpheme production in utterance medial position.

Following the procedures outlined for Experiment 1, the same female speaker was recorded producing the eight new utterance-medial sentences. Praat was used to measure sentence duration, target noun duration, and morpheme duration for each sentence. ANOVA was used to compare each duration type across the eight new utterance-medial sentences and the previously used eight utterance-final sentences. The results for sentence duration showed no main effect of utterance position, $F(1, 6) = 1.15$, $p = .325$, no main effect of coda complexity $F(1, 6) = 0.08$, $p = .783$, and no interaction between the two factors, $F(1, 6) = 1.58$, $p = .256$. In terms of target noun duration, there was the expected main effect of position, $F(1, 6) = 80.43$, $p < .001$, no effect of complexity, $F(1, 6) = 1.63$, $p = .248$, and no interaction between the two, $F(1, 6) = 0.37$, $p = .567$. Also as expected, results for morpheme duration showed a reliable effect of utterance position, $F(1, 6) = 39.40$, $p < .001$, no main effect of coda complexity, $F(1, 6) = 0.15$, $p = .715$, and no interaction between utterance position and coda complexity, $F(1, 6) = 0.01$, $p = .910$. Collectively, these results confirm that the durational characteristics of the auditory prompts were similar to those used in Experiment 1.

Procedure. The procedure was identical to that described for Experiment 1.

Results

The same coding and analysis procedures were used as in Experiment 1. The first coder conducted all acoustic measurements and the second coder remeasured 25% of the utterances; reliability between the two coders was 93%. The few cases of disagreement were resolved by using the marks from the first coder. Mean morpheme production is shown in the right panel of Figure 1. This was submitted to repeated measures ANOVA with the factors of Coda Complexity and Utterance Position. As in Experiment 1, ANOVA showed that morpheme production in Experiment 2 was more robust for targets with simple codas ($M = 67\%$, $SD = 26$) compared to targets with cluster codas ($M = 54\%$, $SD = 22$), $F(1, 13) = 11.69$, $p = .005$; $\eta^2 = .062$. However, in contrast to Experiment 1, ANOVA revealed a main effect of utterance position, $F(1, 13) = 15.35$, $p = .002$; $\eta^2 = .719$, with more morphemes produced in utterance-final ($M = 82\%$, $SD = 27$) compared to utterance-medial (M = 39%, SD = 34) position. There was no interaction between the two factors, $F(1, 13) = 0.24$, $p = .630$; $\eta^2 = .004$.[2]

Discussion

Summary

The goal of the current work was to examine the locus of the utterance position effect on children's early production of grammatical morphemes. More reliable morpheme production utterance-finally compared to utterance-medially has been shown for both third-person singular *–s* (Song et al., 2009) and plural *–s* (Theodore et al., 2011). Such prosodic influences suggest that variability in morpheme production reflects an interaction between differentially developed levels of processing during speech production.

The results of the current work confirm that there are multiple loci for the effect of utterance position on morpheme production. In Experiment 1, when plural *–s* was followed by the articulatory "easy" vowel gesture in utterance-medial position, morpheme production was just as robust in medial position as in final position. Such a pattern of results suggests that whereas increased availability of articulatory planning time due to phrase-final lengthening can enhance morpheme production phrase-finally, morpheme production can also be enhanced phrase-medially by manipulating the local segmental context to contain a following vowel that facilitated simpler articulatory gestures. However, in Experiment 2, when the local articulatory context also included a vowel but differed with respect to global speech planning factors by including an additional syllable to be produced, the positional effect again emerged.

The results for both experiments also showed a robust effect of coda complexity on plural *–s* production that did not interact with utterance position, with greater production in simple codas (e.g., *bees*) compared to cluster codas (e.g., *dogs*). This phonological influence on plural production is consistent with previous findings of such effects for third-person singular *–s* (Song et al., 2009) as well as plural *–s* (Polite, 2011); however, it was not observed in our previous work (Theodore et al., 2011). Close examination of the data presented in Theodore et al. (2011) shows that there was a trend for the coda complexity effect in utterance-final position, but not so for the utterance-medial position, which was near floor performance. It may well be that the challenging articulatory context of the medial utterances in the previous experiment was so great that it negated any facilitative effect of phonological context.

To summarize, the current results point to a complex set of factors that influence children's early production of plural *–s* that include both local and global speech planning considerations. Articulatory planning time alone cannot explain the variability in morpheme production because no positional effect emerged in Experiment 1, where the following vowel context reduced articulatory complexity compared to previous experiments. However, even when these articulatory challenges were reduced in Experiment 2, the positional effect again emerged when processing load was increased. Note that the increase in syllable number for the stimuli in Experiment 2 also introduced the lower frequency words *arrive* and *appear*, as well as a lower frequency (iambic) prosodic structure. It may well be that these factors, along with increased utterance length, all contributed to the lower plural production rates in utterance-medial position. Indeed, research has shown that the relative frequency with which a coda consonant occurs in the lexicon is related to the degree that it is produced in children's speech (Zamuner, Gerken, & Hammond, 2004). Future research will be needed to independently determine the possible effects of these lexical, prosodic, and utterance-length factors on morpheme production.

We acknowledge some limitations of the current work that should be addressed in future investigations. First, there was wide variability in CDI percentile score within each experiment (although it was equivalent between the two experiments), with one child in each experiment scoring below the 16th percentile, even though all parents reported a typical developmental trajectory for each child included in the study. We note that effects of receptive language on speech planning factors should be considered in future work. Second, there was some variability in lexical frequency both with respect to target noun frequency and the inclusion of lower frequency words and prosodic structures used in the utterance-medial sentences for Experiment 2. The influence of each of these factors on production of grammatical morphemes warrants further investigation, both with respect to their independent contributions and potential interactions with speech planning factors.

Clinical Implications

There are at least two implications of our work in the clinical domain. The first concerns diagnosis of language disorders in children. Results of the current work, and other

[2]The two experiments were conceptualized as independent examinations; accordingly, separate ANOVAs were performed as reported in the main text. However, to ensure that the comparisons and generalizations across the two experiments are supported statistically, mean morpheme production across the two experiments was directly compared using ANOVA with Experiment (Experiment 1 vs. Experiment 2) as a between-participants factor and Utterance Position and Coda Complexity as within-participants factors. The results showed no main effect of experiment, indicating that overall morpheme production was equivalent between the two experiments. There were main effects of both position, $F(1, 26) = 11.674$, $p = .002$, and complexity, $F(1, 26) = 19.563$, $p < .001$. It is critical to note that there was an interaction between position and experiment, $F(1, 26) = 6.211$, $p = .019$, reflecting the fact that position influenced morpheme production in Experiment 2, but not in Experiment 1. There was no interaction between complexity and experiment, $F(1, 26) = 2.293$, $p = .593$, or complexity and position, $F(1, 26) = 0.595$, $p = .449$, and the three-way interaction was not significant, $F(1, 26) = 0.000$, $p = 1.000$. This pattern of results is consistent with the patterns demonstrated in the individual ANOVAs and our subsequent joint consideration of the results.

studies in this vein, demonstrate that even for typically developing children, grammatical morpheme production is systematically helped or hindered by complexity at other levels of language representation. This is not surprising given that multiple systems are developing in parallel. These findings suggest that metrics used to define mastery of morpheme production must take a host of other factors into account, including utterance position of the target morpheme, local articulatory difficulty, phonological complexity, and utterance length. Failure to do so may suggest that the locus of a problem is due to an impoverished grammar rather than interactions between grammatical knowledge and other factors. To illustrate, a child who produces a morpheme 50% of the time in one context might perform at ceiling in an easier context (e.g., simple coda in utterance-final position) and may have floor performance in a harder one (e.g., complex coda in utterance-medial position).

A second clinical consideration concerns implications of the current data for rehabilitation protocols. Our findings raise the possibility that recruiting stability at one level of language processing may in fact enhance performance at another, which suggests a possible approach for teaching grammatical morphemes. Specifically, introducing new grammatical knowledge in the context of simple codas in utterance-final position may facilitate processing these morphemes in more challenging contexts. Such approaches are well established in rehabilitation protocols for speech sound disorders, where simple contexts such as CV syllable shapes are mastered prior to moving to more difficult contexts. Additional research is needed to determine if such considerations should constitute best practice for intervention with language disorders, even when articulation and phonological competence is not considered atypical.

Conclusions

Collectively, these results add to a growing body of literature outlining complex interactions between different levels of processing in language acquisition (as reviewed in Demuth, 2014). As multiple systems within and outside of the linguistic system proper develop in parallel, stability at one level influences output at others (Stoel-Gammon, 2011). In moving toward a model of speech and language production that fully describes the developmental trajectory, future work should consider additional interactions among emerging levels of processing. One relatively understudied aspect is how the emerging lexicon interacts with morpheme production, and the degree to which lexical factors such as vocabulary size and lexical status (e.g., high vs. low frequency) might facilitate the use of grammatical knowledge. Future work is aimed at addressing this consideration.

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References

Bloom, L. (1970). *Language development: Form and function in emerging grammars*. Cambridge, MA: MIT Press.

Boersma, P., & Weenink, D. (2010). Praat: Doing phonetics by computer (Version 5.1.25) [Computer program]. Retrieved from http://www.praat.org/

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review, 93,* 283–321.

Demuth, K. (1996). The prosodic structure of early words. In J. Morgan & K. Demuth (Eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition* (pp. 171–184). Mahwah, NJ: Erlbaum.

Demuth, K. (2014). Prosodic licensing and the development of phonological and morphological representations. In A. Farris-Trimble & J. Barlow (Eds.), *Perspectives on phonological theory and development: In honor of Daniel A. Dinnsen* (pp. 11–24). Philadelphia, PA: John Benjamins.

Demuth, K., & McCullough, E. (2009). The prosodic (re)organization of children's early English articles. *Journal of Child Language, 36,* 173–200.

Fenson, L., Pethick, S., Renda, C., Cox, J. L., Dale, P. S., & Reznick, J. S. (2000). Short-form versions of the MacArthur Communicative Development Inventories. *Applied Psycholinguistics, 21,* 95–116.

Gerken, L. A. (1996). Prosodic structure in young children's language production. *Language, 72,* 683–712.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22,* 1–75.

Levelt, W. J. M., & Wheeldon, L. (1994). Do speakers have access to a mental syllabary? *Cognition, 50,* 239–269.

Mealings, K., & Demuth, K. (2014). The role of utterance length and position in three-year-olds' production of third person singular *–s*. *Journal of Speech, Language, and Hearing Research, 57,* 484–494.

Munson, B., Edwards, J., Schellinger, S. K., Beckman, M. E., & Meyer, M. K. (2010). Deconstructing phonetic transcription: Covert contrast, perceptual bias, and an extraterrestrial view of Vox Humana. *Clinical Linguistics & Phonetics, 24,* 245–260.

Polite, E. J. (2011). The contribution of part-word phonological factors to the production of regular noun plural *–s* by children with and without specific language impairment. *First Language, 31,* 425–441,

Song, J., Sundara, M., & Demuth, K. (2009). Phonological constraints on children's production of English third person singular *–s*. *Journal of Speech, Language, and Hearing Research, 52,* 623–642.

Stoel-Gammon, C. (2011). Relationships between lexical and phonological development in young children. *Journal of Child Language, 38,* 1–34.

Theodore, R. M., Demuth, K., & Shattuck-Hufnagel, S. (2011). Acoustic evidence for position and complexity effects on children's coda production. *Journal of Speech, Language, and Hearing Research, 54,* 539–548.

Theodore, R. M., Demuth, K., & Shattuck-Hufnagel, S. (2012). Segmental and position effects on children's coda production: Evidence from acoustic analysis and perceptual judgments. *Clinical Linguistics & Phonetics, 26,* 755–773.

Zamuner, T. S., Gerken, L., & Hammond, M. (2004). Phonotactic probabilities in young children's speech production. *Journal of Child Language, 31,* 515–536.

Zapf, J. A., & Smith, L. B. (2008). Meaning matters in children's plural productions. *Cognition, 108,* 466–476.