JSLHR

Article

Acoustic Investigations Into the Later Acquisition of Syllabic -*es* Plurals

Kiri T. Mealings,[a] Felicity Cox,[a] and Katherine Demuth[a]

Purpose: Children acquire /-əz/ syllabic plurals (e.g., *buses*) later than /-s, -z/ segmental plurals (e.g., *cats, dogs*). In this study, the authors explored whether increased syllable number or segmental factors best explains poorer performance with syllabic plurals.
Method: An elicited imitation experiment was conducted with 14 two-year-olds involving 8 familiar disyllabic target plural nouns, half with syllabic plurals (e.g., *bus* → *buses*) and half with segmental plurals (e.g., *letter* → *letters*). Children saw pictures of the target items on a computer and repeated prerecorded 3-word-utterances with the target word in utterance-medial position (e.g., "The *buses* come") and utterance-final position (e.g., "Hear the *buses*"). Acoustic analysis determined the presence or absence of the plural morpheme and its duration.
Results: Children had more trouble producing syllabic plurals compared with segmental plurals. Errors were especially evident in the utterance-medial position, where there was less time for the child to perceive/produce the word in the absence of phrase-final lengthening and where planning for the following word was still required.
Conclusions: The results suggested that articulatory difficulties—rather than a word length effect—explain later acquisition of syllabic plurals relative to segmental plurals. These findings have implications for the nature of syllabic plural acquisition in children with hearing impairments and specific language impairment.

Key Words: child language acquisition, speech production, acoustic phonetics, syllabic plurals, grammatical morphemes

There are three plural allomorphs in English. Two of these are segmental -*s* plurals /s/ and /-z/, and the other is the syllabic -*es* plural /-əz/. The /-s/ allomorph occurs after voiceless nonsibilant obstruents (e.g., *cat* → *cats* /kæts/).[1] The /-z/ allomorph occurs after voiced-nonsibilant obstruents (e.g., *dog* → *dogs* /dɔgz/), sonorant consonants (e.g., *tail* → *tails* /tælz/), and vowels (e.g., *shoe* → *shoes* /ʃuːz/). The syllabic /-əz/ allomorph is required after sibilants (e.g., *bus* → *buses* /bʊsəz/) and adds an extra syllable to the end of the word.

Children's early production of grammatical morphemes is highly variable. This variability depends on both the phonological environment of the morpheme (e.g., Song, Sundara, & Demuth, 2009) and which morpheme is targeted (e.g., Berko, 1958). In particular, children are reported to acquire the /-əz/ syllabic plural later than /-s, -z/ segmental plurals (Brown, 1973). The aim of this study is to shed light on why these syllabic morphemes present a challenge for typically developing learners, with implications for those with language delays.

Brown (1973) established the order of acquisition of 14 grammatical morphemes by studying the speech of three American children. He found that the plural morpheme was acquired relatively early, between 1;11 (years;months) and 2;10. Its use in the early stages, however, was quite sporadic (see similar reports by Leopold, 1949, for his English–German bilingual daughter). In an imitation experiment on morpheme production with six American children, Brown and Fraser (1963) also reported variable plural production between the ages of 2;1.5 and 2;11.5. Studies involving larger cohorts—such as those by de Villiers and de Villiers (1973); Lahey, Liebergott, Chesnick, Menyuk, and Adams (1992); Paul and Alforde (1993); and Nicholls, Eadie, and Reilly (2011)—have also reported production variability in the early stages of English grammatical morpheme acquisition. These studies show that this variability is evident in not only typically developing monolingual children but also multilingual children and those with language delays.

The classic Berko (1958) study involved a morpheme elicitation task with nonce words to see if American children age 4;0–7;0 possessed morphological rules. She found that children's production rates were high (79%–91%) when forming plurals requiring the /-s/ or /-z/ segmental plural

[1]Because in this study we investigated the speech of Australian children, International Phonetic Alphabet (IPA) transcriptions reflect Australian English vowels (cf. Harrington, Cox, & Evans, 1997).

[a]Macquarie University, Sydney, Australia
Correspondence to Kiri T. Mealings: kiri.mealings@students.mq.edu.au
Editor: Janna Oetting
Associate Editor: Susan Rvachew
Received May 23, 2012
Revision received October 29, 2012
Accepted December 6, 2012
DOI: 10.1044/1092-4388(2012/12-0163)

but were much lower (28%–36%) when the stem ended in a sibilant, where the more complex /-əz/ syllabic plural was required. Marshall (2004) also reported that children with specific language impairment (SLI) omitted more morphemes when naming plural nouns taking the syllabic compared with segmental plural. Berko suggested that children at this age may think that a final sibilant (e.g., *bus*) makes the word plural—hence, the omission of the /-əz/ plural morpheme. However, this theory has limitations, because a word like *bus,* if considered plural, would result from a singular form /bʊ/, which is a phonotactically illegal word form containing a CV-syllable ending in a short vowel. Furthermore, when pluralized, such a word would then take the voiced suffix /bʊ + z/ rather than the voiceless /bʊ + s/.

Goad (1989) suggested that children may use an intermediate "gemination strategy" in acquiring the syllabic plural, resulting in use of two consecutive fricatives (e.g., *bus-s* /bʊss/) prior to learning to epenthesize a schwa. According to McCarthy (1986), replacing gemination with epenthesis is motivated by the *obligatory contour principle*, which states that adjacent identical phonemes are not allowed; therefore, *bus-s,* which ends in a double /s/, must then become *buses*. According to both Berko's and Goad's studies, the later acquisition and variable production of the syllabic *-es* plural could be accounted for by the gradual acquisition of such morphological rules. Thus, the child initially adds nothing to a sibilant-final word, assuming it is already plural (e.g., *bus* → *bus*). Then, the child knows that a morpheme must be added to make the word plural, therefore, he or she adds the simple segmental *-s* morpheme (e.g., *bus* → *bus-s*). Finally, the child understands that this double /s/ (or /z/ in voiced cases) is not allowed; therefore, he or she "antigeminates" (McCarthy, 1986) by using schwa epenthesis to produce the syllabic plural (e.g., *bus* → *buses*), and this is generalized to the other sibilant contexts where syllabic plurals are required—such as after postalveolar sibilants (e.g., *dishes* /dɪʃəz/) and affricates (e.g., *peaches* /piːʧəz/, *judges* /ʤʊʤəz/), where both the place feature (coronal) and manner feature (continuant) are the same (Borowsky, 1987).

Other studies suggest that some of the variability in children's early productions of grammatical morphemes may interact with context effects, including phonological complexity within the coda and durational effects such as word length, stress, and utterance position. Regarding word length, Kirk and Demuth (2006) found that codas of monosyllabic words are produced more accurately than codas of disyllabic words. Monosyllabic words have longer per-syllable durations, with an inverse relationship between the number of syllables in a word and their duration (Ladefoged, 1993; Lehiste, 1972). For example, the monosyllabic word *bake* is the initial syllable in the words *bake, baker,* and *bakery.* However, the duration of this syllable decreases for each additional syllable that is added to the initial word. Kirk and Demuth (2006) also found an advantage of producing codas in stressed syllables, which exhibit increased duration relative to unstressed syllables. Note, however, that the syllabic plural is an unstressed syllable (e.g., *buses* /ˈbʊs-əz/). Thus, the later acquisition of the syllabic *-es* plural may be because of the morpheme occurring in an unstressed syllable at the end of a longer, disyllabic word. This means that there is less time for the articulators to approximate their targets, making it more challenging to produce.

Studies on consonant cluster production in Australian English-speaking 2-year-olds show that these are challenging entities that are often not produced in an adultlike manner (McLeod, van Doorn, & Reed, 2001a, 2001b). Studies of American and U.K. English have also shown the later acquisition of plural, third-person singular, and past-tense morphemes ending in a coda cluster in both typically developing children and children with SLI (Marshall & van der Lely, 2007; Oetting & Horohov, 1997; Polite, 2011; Song et al., 2009). There is also evidence that adding an extra syllable to inflect a word makes it even more difficult for the child to produce than a past tense segmental morpheme that results in a coda cluster (e.g., *melted* /melt-əd/ vs. *baked* /bæɪkt/; Berko, 1958; Marchman, Wulfeck, & Weismer, 1999). This raises the question of whether similar effects occur with plurals. If increased word length is the main contributor to the later acquisition of the syllabic plural, we would expect to find equal difficulties in the production of monosyllabic words requiring the syllabic plural (e.g., *bus* → *bus-es*), and disyllabic words with the segmental plural (e.g., *letter* → *lett-ers*). Note that these plural words take the same CVCəz form in a nonrhotic dialect such as Australian English, providing an ideally controlled set of items for comparison.

In regard to utterance position, Song et al. (2009) also showed that the American children's production of third-person singular *-s* was better in contexts that were phonologically less challenging, such as when the word was in lengthened utterance-final position. Theodore, Demuth, and Shattuck-Hufnagel (2010) also found this utterance position effect in children's production of plural *-s* in monosyllabic words, with lower performance occurring utterance medially. This difference was explained by the phenomenon of *phrase-final lengthening*, in which words produced at the end of a phrase are typically longer in duration than when produced elsewhere in the phrase. The vowels in content words are longer phrase finally in adult-directed speech and even longer in child-directed speech (Swanson, Leonard, & Gandour, 1992). Phrase-final lengthening, therefore, gives the child more time not only to perceive a morpheme but also to plan and produce it. Theodore, Demuth, and Shattuck-Hufnagel (2011) suggested that the difficulty in producing utterance-medial morphemes may be due not only to their shorter duration but also to the demands of planning and articulating the following word (which is not required when the word is utterance final). This study will therefore incorporate utterance position effects to further expose possible morpheme production difficulties.

Another possible explanation for the later acquisition of /-əz/ syllabic plurals may be related to articulatory difficulty. Smit (1993) found that American English fricatives are typically acquired later than stops, with many errors in early productions. The same pattern has been found in Australian English (Chirlian & Sharpley, 1982; Kilminster

& Laird, 1978; McLeod, 2007). Furthermore, complete devoicing of fricatives is relatively common in the younger years, especially for word-final /-z/ (Smith, 1997). *Stopping* of the fricative (i.e., producing a stop instead of, or before, the fricative articulation) also occurs in children but more so for word-initial and word-medial fricatives; fricatives are generally produced without stopping when word final or word medially between a strong and weak syllable (Chiat, 1989). Omission of word-final fricatives, however, is common in children's speech. Using nonmorphemic words, Smit (1993) found only 43% of word-final /-z/ phonemes and 60% of word-final /-s/ phonemes were correctly produced by American children between the ages of 2 and 3 years. These poor results may be because the laryngeal and supralaryngeal articulations for /s, z/ are of greater complexity compared with other speech sounds (Koenig, Lucero, & Perlman, 2008), requiring carefully coordinated tongue positioning and fine control of airflow through a narrow oral constriction to generate the required frication (Kent, 1992). Additionally, voiced fricatives exhibit higher airflow resistance at the glottis and vocal fold vibration (Clark & Yallop, 1995). Between the ages of 2 and 3 years, when tongue muscle tone increases for skilled tongue movement (McLeod & Bleile, 2003), tongue movement is still slower for children than adults (Nittrouer, 1993). This may suggest articulation difficulties for the child who is producing syllabic plurals, as these consist of two fricatives produced in close succession. There is also evidence that schwa is a difficult phoneme for children to produce (e.g., Davies, Yuen, & Demuth, 2011; Goodell & Studdert-Kennedy, 1993; Nittrouer, 1993). It would therefore seem that producing the fricative–schwa–fricative sequences required for words with syllabic plurals is especially challenging for preschool children. Moreover, Berko (1958) found that children were worse at adding the /-əz/ morpheme when the singular also ended in /z/ compared with other phonemes, including /s/. This is in line with Smit's (1993) findings showing increased difficulty in children's production of voiced fricatives word finally compared with their voiceless counterparts.

In summary, previous research points to three possible factors that may contribute to the later acquisition of the syllabic *-es* plural:

1. Children might assume the stem word is already plural because it ends in a sibilant.
2. The longer word length from the extra syllable decreases the articulation time available for each syllable, making it a more difficult production.
3. The fricative–schwa–fricative phoneme sequence is a challenging articulatory sequence for children to produce.

In this study, we aimed to investigate these issues by examining 2-year-old children's production of syllabic *-es* plurals in an elicited imitation task. From previous findings, it was expected that morpheme fragility would be particularly exposed in utterance-medial position (e.g., *The buses come*) compared with utterance-final position (e.g., *Hear the buses*) because of the absence of phrase-final lengthening. In light of this, the following predictions were made:

1. If children assume the stem word is already plural, the syllabic *–es* plural (e.g., *buses* /bʊsəz/) will be omitted regardless of utterance position, but the segmental *–s* plural (e.g., *letters* /letəz/) will be produced.
2. If word length is a factor, there will be no difference between the production of the syllabic plural (e.g., *buses* /bʊsəz/) and the segmental plural in a disyllabic word (e.g., *letters* /letəz/).
3. If segmental–articulatory issues are a factor, there will be more variable productions of the syllabic plural (e.g., *buses* /bʊsəz/) compared with the segmental plural (e.g., *letters* /letəz/), particularly utterance medially.

Method

Participants

The participants were 14 typically developing children (7 male, 7 female) from monolingual Australian English-speaking homes in the Sydney region. All were recruited through brochures displayed at local child care centers and magazine advertisements, in compliance with ethics approval. Parents interested in participating in the study contacted the researcher and were enrolled in the study. The age range was 1;11–2;5 [years;months], with a mean of 2;3. This number of participants provided enough power to reveal significant results and reflects the number of participants used in previous studies of a similar nature (e.g., Song et al., 2009; Theodore et al., 2011). An additional 21 children participated in the experiment but were not included in the analysis because of a lack of speaking during the task (n = 10), producing less than 75% of tokens (n = 1), only repeating after the mother (n = 1), the mother having a Canadian (rhotic) accent (n = 1), or ceiling performance (n = 8). The attrition rate due to lack of speaking or insufficient number of tokens produced is consistent with those found in studies involving similar tasks with children of a similar age group (e.g., Song et al., 2009; Theodore et al., 2011).

All children were reported by their parents to be healthy on the day of testing and to be typically developing in their speech and language skills. The children were screened by otoacoustic emissions or tympanometry for normal hearing. The children's parents were asked to fill out a brief demographic survey and the MacArthur Communicative Development Inventories (CDI) short form 100-word checklist to estimate the children's vocabulary size and assess their communicative skills (Fenson et al., 2000). The MacArthur vocabulary test percentile scores ranged from 20 to 100, with a mean of 63 (SD = 30). A regression analysis revealed no effects of age, CDI score, or gender on morpheme production despite previous studies reporting more advanced language development in girls compared with boys (e.g., Bornstein, Haynes, Painter, & Genevro, 2000; Burmana, Bitanc, & Bootha, 2008; Karmiloff & Karmiloff-Smith, 2002).

Stimuli

Eight target plural nouns were selected for the experiment, four of which had a disyllabic stem ending in a schwa, thereby taking the segmental /z/ plural (e.g., *letter* → *letters*), and four of which had monosyllabic stems ending in the sibilants /s/ or /z/, hence, becoming disyllabic once the syllabic plural was added (e.g., *bus* → *buses*). The four target words of the first group all had a CVCə + z phonemic structure with a stop consonant (two voiced and two voiceless) preceding the schwa. The second group of words were split into two contexts with the phonemic structures CVs + əz and CVz + əz to control for voicing. Each target word appeared in two sentences, one utterance medially and the other utterance finally, as shown in Table 1.

The target words were high-frequency, familiar, picturable nouns with similar lexical frequencies across the two conditions to avoid a confounding frequency effect. The frequencies were extracted via ChildFreq from the CHILDES database, which calculates the child's frequency of saying the target word per million words between 2;0 and 3;0 (Bååth, 2010; MacWhinney, 2000). The sum of the frequencies for the segmental CVCə + z plurals was 126 (range = 2–70), and the sum of the frequencies for syllabic CVs/z + əz plural words was 117 (range = 3–103).

Each stimulus sentence was in the present tense and consisted of two monosyllabic words plus the disyllabic target noun to control for utterance length (i.e., three words with a total of four syllables per sentence in all conditions). To control for any articulatory influences, the target noun in utterance-medial position was always followed by a word that began with a stop (half voiced, half voiceless) at a different place of articulation to the alveolar plural *-s*. This makes the context more challenging and reduces the possibility of resyllabification of the plural with the following word (Theodore et al., 2010). When the target word was in utterance-final position, the preceding words were either *the* or a pronoun, thereby controlling for rhythmic effects across conditions.

An adult female native speaker of Australian English was recorded producing the 16 sentences for the stimuli using child-directed speech. The recording took place in a sound-attenuated room using a Behringer C-2 microphone and Pro Tools LE software at a sampling rate of 44.1 kHz. Each sentence was then segmented using Praat software (Boersma & Weenink, 2011). The average schwa and fricative durations for both the syllabic and segmental plurals are shown in Table 2. The duration of the word-final *-es* syllable was on average 83.33% longer when the target word was in utterance-final position compared with utterance-medial position. This served as a baseline for later exploring the same issues in the children's speech. All word-final fricatives in the adult model were (at least partially) voiced, as evident from the presence of a voice bar.

Each target noun was paired with a picture to serve as a visual prompt during the experiment. All pictures were real photos with minimal background distractions. Each picture appeared twice on the computer display to represent the plural. Zapf and Smith (2008) found that children were much more likely to produce the plural of well-known nouns presented as identical objects rather than similar objects (e.g., having two dogs of the same type rather than two dogs of different breeds). Each of the 16 stimulus prompts were pseudorandomized into two blocks and alternated across participants to minimize possible order effects.

Procedure

The children and parents were invited into a sound-attenuated test room containing a child-sized table and chairs, with a computer monitor and speakers on top of the table. After becoming familiarized with the experimenter by playing with a picture book or toys, the children were invited to play a language game. The room was equipped with two computers (one used for the stimulus display and the other for recording), Sony SRS-55 speakers, and a Behringer C-2 microphone. The microphone was placed on the table near the children to best capture their speech. Children were asked to watch the pictures on the computer monitor and repeat what they heard. The experiment began with a brief warm-up to familiarize the children with the task and to check the sound levels. Once the children were ready, the test items began. The presentation started with the auditory direction, "Say what I say!" For each item, pictures of the target nouns appeared on the monitor along with the auditory prompt. If needed, three attempts were allowed for each utterance to obtain an acoustically acceptable recording to be analyzed. The children were encouraged with praise and stickers for each trial. The entire procedure took approximately 30 min. The children were given a T-shirt and/or stickers, and the parents received a gift card for their time.

Table 1. Target plural nouns and their corresponding stimulus sentences.

Plural type		Target	IPA	Utterance medial	Utterance final
Segmental	CVCə + z	Letters	/letəz/	My letters come	Send my letters
		Tigers	/tɑegəz/	His tigers bite	Pat his tigers
		Bakers	/bæɪkəz/	The bakers cook	See the bakers
		Ladders	/lædəz/	The ladders break	Climb the ladders
Syllabic	CVs + əz	Horses	/hoːsəz/	Her horses kick	See her horses
		Buses	/bɐsəz/	The buses come	Hear the buses
	CVz + əz	Noses	/nəuzəz/	Their noses blow	Touch their noses
		Hoses	/həuzəz/	The hoses bend	Pull the hoses

Table 2. Average schwa and fricative durations by plural type and utterance position for the adult model.

Utterance position	Average schwa duration (in ms)		Average fricative duration (in ms)	
	Segmental	Syllabic	Segmental	Syllabic
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Medial	133 (23)	106 (10)	117 (18)	106 (23)
Final	201 (11)	172 (18)	245 (17)	246 (12)

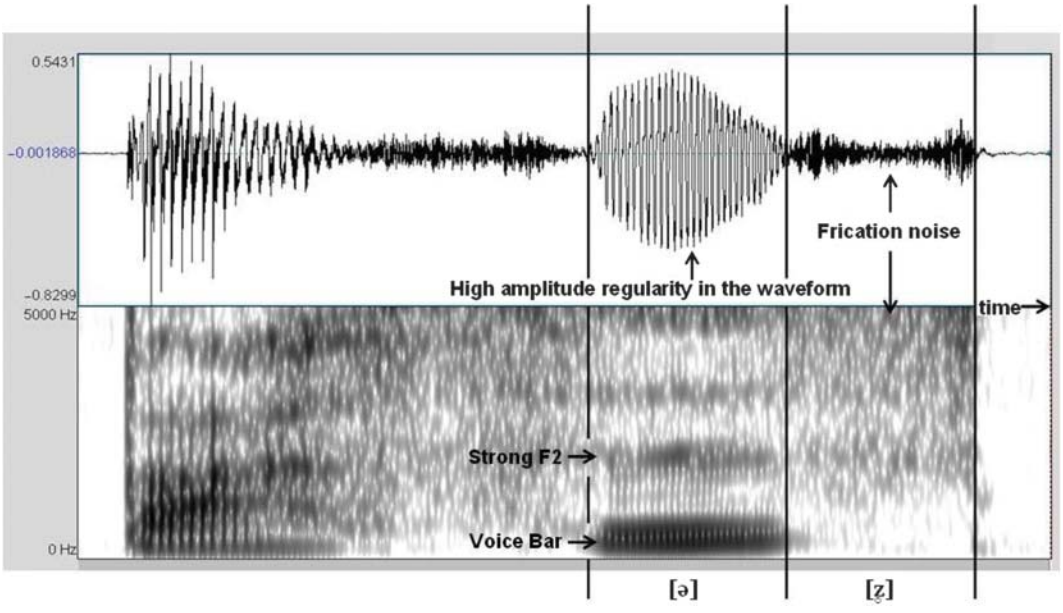
Acoustic Coding and Analysis

Acoustic analysis was used to provide greater accuracy than simply relying on human perception and impressionistic transcription methods, as contrasts made by the speaker may not be detected by the listener (Scobbie, 1998). Li, Edwards, and Beckman (2009), who studied fricative production in 2- and 3-year-old children and in adults, found transcription by itself an inadequate way to describe phonological acquisition. This is because it uses adults' perceptual norms to determine children's productions. They, therefore, concluded that acoustic analysis is a more objective and unbiased method to measure these productions; hence, it is the method adopted for this study (see also Theodore, Demuth, & Shattuck-Hufnagel, 2012).

The children's utterances were recorded using Pro Tools LE at a sampling rate of 44.1 kHz, then excized and coded by a trained coder using Praat (Boersma & Weenink, 2011). Of the 224 tokens, 25 were excluded because the child said only the target word (n = 3), the produced word was either incorrect (e.g., *ho-eh* [hoːwə] for *hoses*) or unintelligible (n = 10), or the acoustic quality was poor from noise interference (n = 12). The remaining 199 tokens (50 segmental plural utterance-medial tokens, 51 syllabic plural utterance-medial tokens, 45 segmental plural utterance-final tokens, 53 syllabic plural utterance-final tokens) were coded by submitting the final three phonemes of each target word to acoustic analysis. Each acoustic cue was identified by visual inspection of the waveform and wideband spectrogram while listening to the utterance. The acoustic coding criterion was based on Stevens's (2002) and Stevens and Keysers's (2010) feature cue–based model. Figure 1 shows a representative waveform and spectrogram illustrating the cues of interest and their segmentation.

After identifying and coding the preceding stop or fricative, the first cue to *-es* production was the presence of high-amplitude regularity in the waveform and a strong second formant (F2) representing the resonant properties of the schwa vowel. The second cue following the periodicity for the vowel was high-frequency aperiodic frication noise representing the vocal tract constriction for the sibilant phoneme /z/. We used the presence or absence of word-final frication to determine whether the segmental *-s* plural was realized for the CVCə + z words. For the CVs/z + əz syllabic plural words, we used the presence or absence of both the schwa and word-final frication to determine whether the syllabic *-es* plural was realized. Voiceless realizations for voiced coda consonants are common in children's early productions (Naeser, 1970; Smit, 1993). Thus, [bɐsəz], [bɐsəz̥], and [bɐsəs] were all counted as the plural being realized. The final /ə/ and /z/ durations of the target words were measured so that utterance position effects could be compared. All of the tokens were initially coded by one trained coder and then checked

Figure 1. Representative waveform and spectrogram from an adult speaker showing acoustic landmarks for the target word *buses*.



again by this coder for consistency. A second trained coder then coded 10% of the tokens for the schwa, fricative, and voicing acoustic events. Reliability for the presence of fricative, schwa, and voicing events was 100%. Reliability between the two coders on the durational measures (within ±25 ms) was 70% for the fricative and 85% for schwa. The range in durational discrepancies for the fricative was 1 ms–101 ms, with a mean of 23 ms (SD = 30). For schwa, the range in discrepancies was 0 ms–33 ms, with a mean of 12 ms (SD = 9).

Results

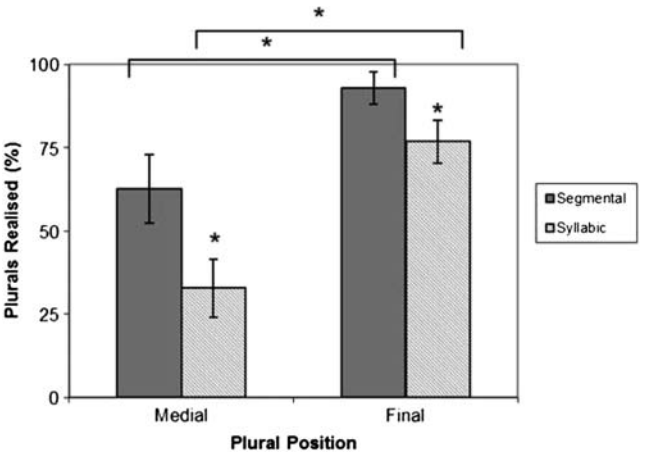
Plural Realizations

The mean number of plural productions across children was submitted to a repeated-measures analysis of variance (ANOVA). The variables of plural type (segmental vs. syllabic) and utterance position (medial vs. final) were used. The ANOVA results showed a main effect for plural type, $F(1, 52) = 8.463$, $p < .05$, $\eta_p^2 = .140$, indicating that, overall, the segmental plural was produced significantly more often (78%) than the syllabic plural (55%). A second main effect was also revealed for utterance position, $F(1, 52) = 22.304$, $p < .05$, $\eta_p^2 = .300$, indicating that the plural morpheme was produced in a greater proportion of utterance-final tokens (85%) compared with utterance-medial tokens (48%). No interaction was revealed between plural type and utterance position, $F(1, 52) = 0.755$, $p = .389$, $\eta_p^2 = .014$. A series of paired t tests was conducted to determine significant differences between conditions. The four conditions examined were utterance position effects according to plural type and plural type effects according to utterance position. Bonferroni corrections were used to account for the multiple comparisons, therefore, an alpha level of .05 was adjusted to $\alpha = .05/4 = .0125$. The results revealed an utterance position effect, with plural production significantly worse utterance medially compared with utterance finally for both the segmental plural, $t(13) = -2.668$, $p < .0125$, $d = -1.047$, and the syllabic plural, $t(13) = -5.108$, $p < .0125$, $d = -1.585$. The results also showed a plural type effect, with plural production significantly worse for the syllabic plural compared with the segmental plural in both utterance-medial, $t(13) = 3.597$, $p < .0125$, $d = 0.860$, and utterance-final position, $t(13) = 2.728$, $p < .0125$, $d = 0.787$. This is shown in Figure 2.

A further analysis was conducted to examine the types of errors. In utterance-medial position, the entire syllabic plural morpheme was omitted only 10% of the time (e.g., *bus* [bɐs]). When partially realized, the *-s* was sometimes produced without the schwa (4% of attempts, e.g., *bus-s* [bɐss] or [bɐsz] when there was a voice bar). The distinction between this double-fricative production rather than just one long fricative was made clear through examination of the speech waveform. Figure 3 shows a tapering off in the amplitude of the noise in the waveform from the first fricative, followed immediately by an increase in the amplitude of the noise indicating a second fricative but with no periodicity between the two to represent the schwa vowel.

However, the most common partial realization of the syllabic plural was when only the schwa was produced without the word-final fricative (e.g., *buseh* [bɐsə] for *buses*). This occurred in 51% of the attempted syllabic plurals in utterance-medial position. Figure 4 shows this partial realization for the target word *hoses* in the sentence, *The hoses bend,* where the child produced *hoseh* [həʉzə] without word-final frication before closure for the following /b/ in *bend.* Figure 5 provides a closer look at the realizations of the syllabic plural, including the correct /əz/ production plus the three types of errors: /z/ and /ə/ partial morpheme productions and complete morpheme omission. In utterance-medial position, many productions were the /ə/ partial morpheme errors, but in utterance-final position, the children correctly produced the /əz/ morpheme 77% of the time.

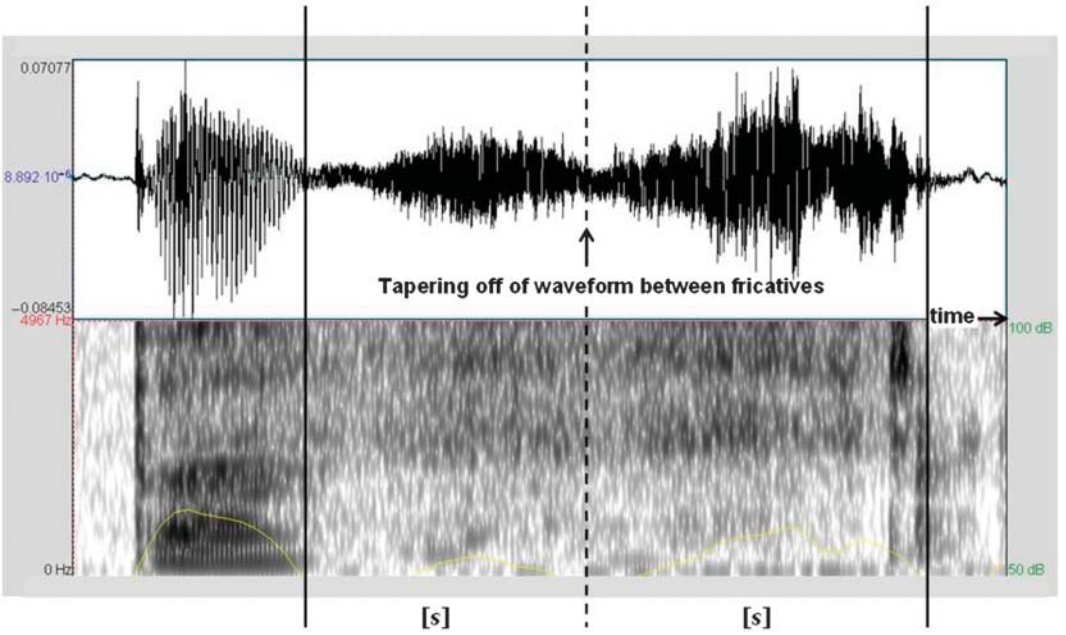
Figure 2. Mean percentage of segmental and syllabic plurals realized for medial and final utterance positions. Error bars indicate standard error of the mean. *$p < .0125$.



Following Smit (1993), it may be expected that the production of the syllabic plural is affected by the voicing of the previous fricative, with children having more trouble producing the syllabic plural when it follows the voiced fricative /z/ (i.e., *hoses* /həʉz̲əz/, *noses* /nəʉz̲əz/) compared with the voiceless fricative /s/ (i.e., *buses* /bɐs̲əz/, *horses* /hoːs̲əz/). Statistical analysis from a paired t test, however, revealed no significant differences between the two in either utterance-medial position (mean percentage of syllabic plural productions after /s/ = 35.71%, SD = 4.13; after /z/ = 28.57%, SD = 3.23), $t(13) = 0.806$, $p = .217$, $d = 0.200$, or utterance-final position (mean percentage of syllabic plural productions after /s/ = 82.14%, SD = 3.17; after /z/ = 78.57%, SD = 3.23), $t(13) = 0.268$, $p = .396$, $d = 0.116$. Note, however, that utterance medially, children produced the stem fricative as voiceless (i.e., *noses* [nəʉs̲əz], *hoses* [həʉs̲əz]) for seven out of 29 tokens when the full syllabic plural was produced, four out of 18 tokens when the plural was partially produced, and two out of four tokens when the plural was completely omitted.

As the most frequent realization of the syllabic plural in utterance-medial position was production of schwa only,

Figure 3. Representative waveform and spectrogram for child's production of *bus-s*.



it might be expected that the children would lengthen this vowel to compensate for the missing coda fricative. An independent-samples *t* test, however, showed no significant difference in the duration of the schwa when the fricative was produced (M = 152 ms, SD = 2) versus omitted (M = 158 ms, SD = 1), $t(42) = 0.250$, $p = .402$, $d = 0.079$.

For the segmental plural words, there were considerably fewer errors, and most were fricative omissions. One

Figure 4. Waveform and spectrogram for child's production of "The *hoseh* (hoses) bend."

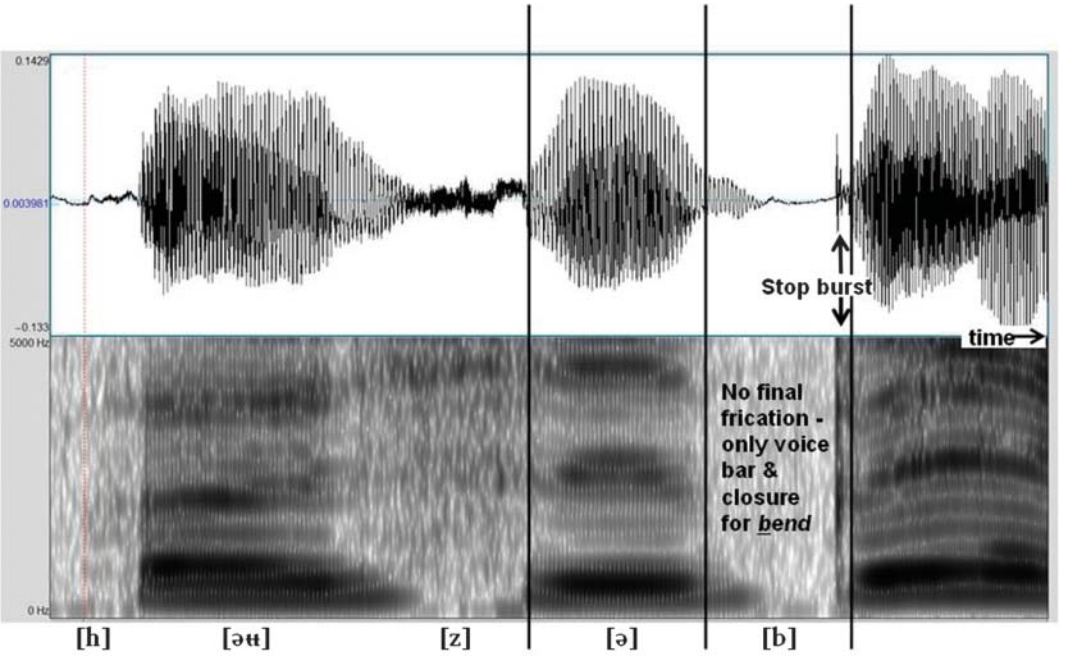
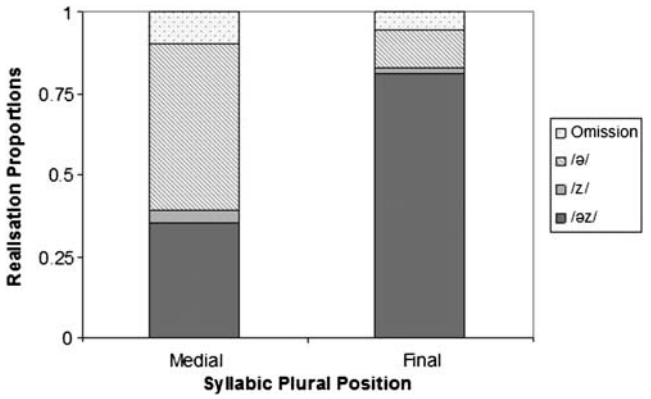


Figure 5. Syllabic plural acoustic realizations for medial and final utterance positions.



child added *leh* [lə] to the end of *letter* (i.e., [letələ]) and *tiger* (i.e., [t^{h}ɑeɡələ]) utterance medially but produced the target plural when these words were in utterance-final position. This indicates that the child knew something was added to the end of the word but appended an entire CV syllable rather than the single plural segment. Song et al. (2009) similarly reported a child adding epenthetic schwa to third-person singular verbs in utterance-medial position (e.g., *He flies fast* [hi: flɑezə̲ fɐ:st]), possibly to avoid having two adjacent consonants.

Children occasionally exhibited stopping before production of the fricative (e.g., *laddeds* [lædə̲d̲z] for *ladders*; once in three different children). Chiat (1989) suggested that stopping occurs at the articulatory planning and motor execution stage, after lexical retrieval. The children's epenthesized consonant was always an alveolar stop, which is the same place of articulation for the /z/ phoneme. Hence, this production may have been an overshoot of the fricative target, which requires more complex control of tongue placement. Therefore, the stop articulation is likely to have been the initial though unintended realization before the fricative. One child consistently produced a glottal stop between the schwa and fricative for both the segmental and syllabic plural words when the target word was in utterance-final position (e.g., *buses* [bʁsə̲ʔs], *letters* [letə̲ʔs]). This too may have been an intermediary articulation in the transition from the schwa to the challenging fricative.

Durational Utterance Position Effects

As mentioned earlier, previous studies have reported durational differences according to the position of a word in a sentence, with utterance-final words typically being subject to phrase-final lengthening. This, in turn, may influence the production of grammatical morphemes in utterance-medial positions (Hsieh, Leonard, & Swanson, 1999; Song et al., 2009). To examine the statistical significance of these utterance position effects, we submitted the mean schwa durations and fricative durations across children to a repeated-measures ANOVA. The factors of utterance position (medial vs. final) and plural type (segmental vs. syllabic) were used. The ANOVA results showed a main effect for utterance position for both the schwa duration $F(1, 52) = 28.035$, $p < .05$, $\eta_p^2 = .350$ and the fricative duration, $F(1,52) = 34.698$, $p < .05$, $\eta_p^2 = .400$, indicating that these phonemes were significantly longer in duration, when in utterance-final position (M[schwa] = 259 ms; M[fricative] = 233 ms) compared with utterance-medial position (M[schwa] = 147 ms; M[fricative] = 89 ms). The ANOVA results for plural type were not significant for either the schwa duration, $F(1, 52) = 0.000$, $p = .988$, $\eta_p^2 = .000$, or the fricative duration, $F(1, 52) = 0.005$, $p = .946$, $\eta_p^2 = .000$, indicating that phrase-final lengthening was present for both the segmental plural and the syllabic plural, and there was no significant difference between the schwa durations (M[segmental] = 203 ms; M[syllabic] = 203 ms) or fricative durations (M[segmental] = 162 ms; M[syllabic] = 160 ms), respectively. No interaction was found between utterance position and plural type for the schwa, $F(1, 52) = 0.040$, $p = .842$, $\eta_p^2 = .001$, or fricative, $F(1, 52) = 0.123$, $p = .727$, $\eta_p^2 = .002$.

A similar analysis was conducted on the adult model to assess the extent to which children have adultlike productions. Recall that for the children, the schwa duration ANOVA results for segmental verses syllabic plural type were not significant. For the adult, however, the schwa duration differences for plural type were significant, $F(1, 12) = 11.351$, $p < .05$, $\eta_p^2 = .486$, with the syllabic plural schwa significantly shorter than the lexical stem schwa for the segmental plural words. To further examine this difference, independent-samples t tests were conducted to compare the schwa durations for each plural type between the children and adult (see Table 3).

These results show that the adult model, which the child had to repeat, contained a reduced schwa in the morphemic syllabic plural /-əz/ compared with the schwa that formed part of the lexical stem for the segmental plural words. The children, however, did not make this morphological distinction. Their syllabic plural durations were also much more variable, exhibiting both intra- and interspeaker variability. Although three of the children showed significant shortening of the syllabic plural schwa, this only occurred in utterance-final position for two of the children and only in utterance-medial position for the other child. As we are unable to comment on whether the adult's productions are typical of the broader population, these results are only tentative but do suggest children's early syllabic plural productions may not yet be adultlike. This is consistent with reports of children's late acquisition of adultlike schwa reduction (e.g., Davies et al., 2011; Nittrouer, 1993; Yuen, Demuth, & Johnson, 2011).

Discussion

Children's early productions of grammatical morphemes have been found to be highly variable depending on the phonological environment and the particular morpheme in question. Of particular interest in this study was

Table 3. Mean schwa durations for children and adults.

Position	Context	Child durations (in ms) *M (SD)*	Adult durations (in ms) *M (SD)*	*df*	*t*	*p*
Medial	Segmental	149 (50.35)	133 (22.68)	16	–0.59	0.281
	Syllabic	144 (41.88)	106 (10.42)	16	–1.78	0.047*
Final	Segmental	257 (106.02)	201 (11.47)	16	–1.04	0.156
	Syllabic	261 (98.80)	172 (18.19)	16	–1.75	0.049*

*Significant at α = .05.

that children acquire /-əz/ syllabic plurals later than /s, z/ segmental plurals. The aim of our study was to determine which factors best explain this later acquisition of the syllabic plural. We therefore explored three possibilities: (a) sibilant final stems have ambiguous morphophonemic status; (b) longer words increase the motor planning challenge, especially in utterance-medial position; and (c) fricative–schwa–fricative phoneme sequences are especially difficult to articulate accurately.

According to the first hypothesis, an indicator that the children assume the stem words are already plural because they end in a sibilant would be omission of the syllabic plural. The results, however, did not support this hypothesis, with the syllabic plural being produced well in utterance-final position, where there is more time to do so because of phrase-final lengthening. Furthermore, when the target word was in utterance-medial position, it was uncommon for the child to produce only the singular form. On most occasions when the syllabic plural was not realized, the schwa component of the morpheme was still produced, indicating that the child was aware of an additional inflexion. There were a few occasions when the child produced a double fricative (e.g., *bus-s,* i.e., [bɐss] or [bɐsz]), which could be construed as an example of the gemination strategy as described by Goad (1989), but we noted that it occurred in only 2.5% of syllabic plural errors. Given the variable realization of the syllabic plural morpheme in different contexts rather than its complete absence, we found little support for the suggestion that the later acquisition of the syllabic plural is because children assume words ending in a sibilant are already plural.

Alternatively, if word length were a factor in plural morpheme production, we would predict no difference in the production of the disyllabic segmental plural and the syllabic plural; poor production would be expected for both. The results showed, however, that there was a significant difference in the plural productions across plural type, with significantly more morpheme reductions for the syllabic plural compared with the disyllabic segmental plural, particularly in utterance-medial position. As both plural types were represented by disyllabic words with the same CVCəz segmental structures, it is unlikely that increased word length is the main factor contributing to their later acquisition.

In contrast, the results of this study showed that children were significantly worse at producing the syllabic plural compared with the segmental plural, especially when it occurred in utterance-medial position. This suggests that segmental articulatory problems may be an important factor. The partial realizations of the syllabic plural found predominantly in utterance-medial position (e.g., [bɐsə, bɐss, bɐsz]) provide further evidence of these articulation difficulties. They demonstrate that the children recognized that something is added to the end of the noun but have difficulty articulating the entire morpheme, as it involves the complex fricative–schwa–fricative phoneme sequence.

It is interesting that there was no compensatory lengthening of the schwa or substitute productions for the syllabic plural when the fricative was not present in utterance-medial position (i.e., the *buseh* [bɐsə] realizations). This could be interpreted as children thinking that they have produced the morpheme. It is likely, however, that the syllabic plural representation is still fragile, so the planning required for the following word may have superseded children's ability to finish the morpheme, as they were already focusing on the next word.

An additional finding from this study was that the adult speaker recorded for the auditory prompts reduced the duration of the schwa in the syllabic plural (e.g., /bɐsə̲z/) significantly more than the schwa in the lexical item of the segmental plural words (e.g., /letə̲z/). Although one needs to be cautious in drawing conclusions from only one speaker, it is possible that adults reduce the duration of the schwa when it is part of the syllabic plural /-əz/ to distinguish it as a morphemic unit in contrast to being part of the lexical stem. Other studies have shown distinctions between morphemic and nonmorphemic segments. For example, Walsh and Parker (1983) reported that morphemic /s/ (e.g., *laps*) is longer in duration than nonmorphemic /s/ (e.g., *lapse*). Song, Demuth, Shattuck-Hufnagel, and Ménard (2013) also found an articulatory morphemic effect in monomorphemic versus bimorphemic word-final clusters (e.g., *box* /bɔks/ vs. *rocks* /ɹɔks/), using ultrasound methods. The children in our study, however, did not make a durational distinction between the syllabic plural schwa and the lexical stem schwa, perhaps because of children's general difficulty with schwa reduction (Yuen et al., 2011).

Another possible explanation for the later acquisition of the syllabic plural might be because of frequency effects. The syllabic plural is less common in occurrence than the segmental plural, therefore, children may not hear or have as much practice producing it as the segmental plural, thereby postponing its acquisition. Although overall production of

the syllabic plural on nonce words was poor, Berko (1958) did find that children could correctly produce the high-frequency familiar word *glasses*. However, the word *glasses* is somewhat problematic as it can mean the plural of *drinking glasses* as well as the plural dominant word referring to *a pair of reading glasses.* Although the sentential context in Berko's study made it clear that she was referring to the plural of *drinking glasses* ("This is a glass. Now there is another one. There are two of them. There are two __"), the high frequency of the plural dominant form may have contributed to its more accurate production. Brown (1973) suggested that early morpheme acquisition may be a mix of the child memorizing plural words while they are learning the morpheme rules. Although we controlled the lexical frequency of the target words chosen for this experiment—with equal summed frequencies for the segmental and syllabic plural words—the fact that, in general, there are more words ending in /-s, -z/ rather than /-əz/ may be a contributing factor. Out of 1 million words from a sample of 2-year-olds, children used 86,155 words ending in /-s, -z/ but only 387 words ending in /-səz, -zəz/, plus another 782 words ending in /-ʃəz, -ʧəz, -ʤəz/ (frequencies calculated using ChildFreq from the CHILDES database; Bååth, 2010; MacWhinney, 2000). Hence, this much lower frequency of occurrence of the syllabic plural may be a significant contributor to this morpheme's later acquisition.

Of course, the more accurate production of the syllabic plural morpheme in utterance-final compared to utterance-medial position may not be fully explained by limitations in motor or articulatory control alone. For example, Sundara, Demuth, and Kuhl (2011) measured the looking–listening times of grammatical versus ungrammatical sentences (e.g., "She *eats* now" vs. "She *eat* now") with third person singular target words in both utterance-medial and utterance-final positions. They found that children aged 1;10 and 2;3 were perceptually sensitive to the presence or absence of the morpheme when it was in utterance-final position but not when it was in utterance-medial position. The fact that the morpheme is shorter in duration in utterance-medial position means that there is less time to articulate it but also less time to perceive it before attention is diverted to the following word. Thus, it is possible that perception may also have an important role in explaining some of the variability in syllabic plural morpheme production, especially in utterance-medial position.

The findings from this study raise many issues for further research. First, it would be interesting to look at syllabic plural production after other sibilants, such as /ʃ/ in *dishes* /dɪʃəz/ and the affricates /ʧ/ in *peaches* /piːʧəz/ and /ʤ/ in *judges* /ʤʌʤəz/). If, as we predict, the production of these words are realized like the /s, z/-final monosyllabic stems in our study, then this would align with our articulatory account that there is something additionally challenging about the fricative–schwa–fricative sequences. Second, it would be interesting to compare the adult data presented in this study to that of a larger group of adult speakers to determine the robustness of the adult schwa and fricative durations reported here. This could include using both child-directed and adult-directed speech, as the schwa durations differ between the two (Swanson & Leonard, 1994; Swanson et al., 1992). This would provide more insight into the extent to which children at this age are starting to develop adultlike articulations. Third, it would be of interest to carry out a comprehension study to test more directly the hypothesis that children omit the syllabic plural because they believe that the sibilant stem is already plural or whether it is purely a production problem. Finally, it would be interesting to conduct a perception study to examine children's sensitivity to the presence or absence of syllabic plural morphemes in various contexts. This could be especially relevant for addressing related perception and production issues for children with hearing impairment who have marked delays for fricative acquisition (Stelmachowicz, Pittman, Hoover, Lewis, & Moeller, 2004) and grammatical morpheme deficits in children with SLI (Leonard, Eyer, Bedore, & Grela, 1997; Tomas, Demuth, & Smith-Lock, 2012).

Conclusion

In this study, we aimed to investigate the reasons for the later acquisition of the syllabic *-es* plural in 2-year-old children by using an elicited imitation production task. Children were significantly worse at producing the syllabic *-es* plural (e.g., *buses*) compared with the segmental *-s* plural in disyllabic words (e.g., *letters*), particularly when the target word occurred in utterance-medial position. This difference was primarily accounted for by an articulatory difficulty in the execution of the fricative–schwa–fricative sequence required for syllabic plurals, which is especially evident in utterance-medial position where there is less time to articulate the sequence without phrase-final lengthening. Further research is needed to examine the possible effects of segmental and syllabic plural lexical frequencies as well as the perceptual correlates of these morphemes in utterance-medial position. These findings hold important implications for the acquisition of morphemes in populations with language delays, such as those with hearing loss and SLI. Finally, these results contribute to a growing body of literature showing a close link between phonological and morphological development.

Acknowledgments

This research was supported, in part, by funding from Macquarie University and from Australian Research Council (ARC) Grants ARC DP110102479 (awarded to Felicity Cox) and ARC CE110001021 (awarded to Crain et al.), as well as funding from National Institutes of Health Grant R01HD057606 (awarded to Katherine Demuth and Stefanie Shattuck-Hufnagel). Portions of this research were presented at the ARC Centre of Excellence in Cognition and its Disorders Annual Workshop, Macquarie University, Sydney, Australia, in November 2011; the 42nd Annual Conference of the Australian Linguistics Society, The Australian National University, Canberra, Australia, in December 2011; and the Experimental Psychology Conference, The University of New South Wales, Sydney, Australia, in April 2012. We thank Robert Mannell, Kelly Miles, Nan Xu, Ivan Yuen, and the Child Language

Lab at Macquarie University, Sydney, Australia, for helpful assistance and feedback.

References

Bååth, R. (2010). ChildFreq: An online tool to explore word frequencies in child language. *LUCS Minor,* 16.

Berko, J. (1958). The child's learning of English morphology. *Word, 14,* 150–177.

Boersma, P., & Weenink, D. (2011). Praat: Doing phonetics by computer (Version 5.2.23) [Computer program]. Retrieved from www.praat.org

Bornstein, M. H., Haynes, O. M., Painter, K. M., & Genevro, J. L. (2000). Child language with mother and with stranger at home and in the laboratory: A methodological study. *Journal of Child Language, 27,* 407–420.

Borowsky, T. (1987). Antigemination in English phonology. *Linguistic Enquiry, 18,* 671–678.

Brown, R. (1973). *A first language: The early stages*. Cambridge, MA: Harvard University Press.

Brown, R., & Fraser, C. (1963). The acquisition of syntax. In C. N. Cofer & B. S. Musgrave (Eds.), *Verbal behaviour and learning* (pp. 158–197). New York, NY: McGraw-Hill.

Burmana, D. D., Bitanc, T., & Bootha, J. R. (2008). Sex differences in neural processing of language among children. *Neuropsychologia, 46,* 1349–1362.

Chiat, S. (1989). The relation between prosodic structure, syllabification and segmental realization: Evidence from a child with fricative stopping. *Clinical Linguistics & Phonetics, 3,* 223–242.

Chirlian, N. S., & Sharpley, C. F. (1982). Children's articulation development: Some regional differences. *Australian Journal of Human Communication Disorders, 10,* 23–30.

Clark, J., & Yallop, C. (1995). *An introduction to phonetics and phonology* (2nd ed.). Oxford, England: Blackwell.

Davies, B., Yuen, I., & Demuth, K. (2011). *Learning the quality and quantity of English schwa*. Paper presented at the 42nd Annual Conference of the Australian Linguistics Society, The Australian National University, Canberra.

de Villiers, J. G., & de Villiers, P. A. (1973). A cross-sectional study of the acquisition of grammatical morphemes in child speech. *Journal of Psycholinguistic Research, 2,* 267–278.

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.

Goad, H. (1989). The function of the obligatory contour principle in English: Evidence from child language. *Papers and Reports on Child Language Development, 28,* 115–122.

Goodell, E. W., & Studdert-Kennedy, M. (1993). Acoustic evidence for the development of gestural coordination in the speech of 2-year-olds: A longitudinal study. *Journal of Speech and Hearing Research, 36,* 707–727.

Harrington, J., Cox, F., & Evans, Z. (1997). An acoustic phonetic study of broad, general, and cultivated Australian English vowels. *Australian Journal of Linguistics, 17,* 155–184.

Hsieh, L., Leonard, L. B., & Swanson, L. A. (1999). Some differences between English plural noun inflections and third singular verb inflections in the input: The contribution of frequency, sentence position, and duration. *Journal of Child Language, 26,* 531–543.

Karmiloff, K., & Karmiloff-Smith, A. (2002). *Pathways to language*. Cambridge, MA: Harvard University Press.

Kent, R. D. (1992). The biology of phonological development. In C. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 65–90). Timonium, MD: York Press.

Kilminster, M. G. E., & Laird, E. M. (1978). Articulation development in children aged three to nine years. *Australian Journal of Human Communication Disorders, 6,* 23–30.

Kirk, C., & Demuth, K. (2006). Accounting for variability in 2-year-olds' production of coda consonants. *Language Learning and Development, 2,* 97–118.

Koenig, L. L., Lucero, J. C., & Perlman, E. (2008). Speech production variability in fricatives of children and adults: Results of functional data analysis. *The Journal of the Acoustical Society of America, 124,* 3158–3170.

Ladefoged, P. (1993). *A course in phonetics* (3rd ed.). Fort Worth, TX: Harcourt Brace.

Lahey, M., Liebergott, J., Chesnick, M., Menyuk, P., & Adams, J. (1992). Variability in children's use of grammatical morphemes. *Applied Psycholinguistics, 13,* 373–398.

Lehiste, I. (1972). The timing of utterances and linguistic boundaries. *The Journal of the Acoustical Society of America, 51,* 2018–2024.

Leonard, L. B., Eyer, J. A., Bedore, L. M., & Grela, B. G. (1997). Three accounts of the grammatical morpheme difficulties of English-speaking children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 40,* 741–753.

Leopold, W. F. (1949). *Speech development of a bilingual child: A linguist's record. Vol. IV: Diary from age 2*. Evanston, IL: Northwestern University Press.

Li, F., Edwards, J., & Beckman, M. E. (2009). Contrast and covert contrast: The phonetic development of voiceless sibilant fricatives in English and Japanese toddlers. *Journal of Phonetics, 37,* 111–124.

MacWhinney, B. (2000). *The CHILDES project* (3rd ed.). Mahwah, NJ: Erlbaum.

Marchman, V. A., Wulfeck, B., & Weismer, S. E. (1999). Morphological productivity in children with normal language and SLI: A study of the English past tense. *Journal of Speech, Language, and Hearing Research, 42,* 206–219.

Marshall, C. (2004). *The morpho-phonological interface in specific language impairment*. Unpublished doctoral dissertation, University of London, England.

Marshall, C., & van der Lely, H. (2007). The impact of phonological complexity on past tense inflection in children with Grammatical-SLI. *Advances in Speech-Language Pathology, 9,* 191–203.

McCarthy, J. J. (1986). OCP effects: Gemination and antigemination. *Linguistic Inquiry, 17,* 207–263.

McLeod, S. (2007). Australian English speech acquisition. In S. McLeod (Ed.), *The international guide to speech acquisition* (pp. 241–256). Clifton Park, NY: Thomson Delmar Learning.

McLeod, S., & Bleile, K. (2003, November). *Neurological and developmental foundations of speech acquisition*. Seminar presentation at the American Speech-Language-Hearing Association Convention, Chicago, IL.

McLeod, S., van Doorn, J., & Reed, V. A. (2001a). Consonant cluster development in two-year-olds: General trends and individual difference. *Journal of Speech, Language, and Hearing Research, 44,* 1144–1171.

McLeod, S., van Doorn, J., & Reed, V. A. (2001b). Normal acquisition of consonant clusters. *American Journal of Speech-Language Pathology, 10,* 99–110.

Naeser, M. (1970). *The American child's acquisition of differential vowel duration* (Tech. Rep. No. 144). The Wisconsin Research and Development Center for Cognitive-Learning.

Nicholls, R. J., Eadie, P. A., & Reilly, S. (2011). Monolingual versus multilingual acquisition of English morphology: What can we expect at age 3? *International Journal of Language & Communication Disorders, 46,* 449–463.

Nittrouer, S. (1993). The emergence of mature gestural patterns is not uniform: Evidence from an acoustic study. *Journal of Speech and Hearing Research, 36,* 959–972.

Oetting, J. B., & Horohov, J. E. (1997). Past-tense marking by children with and without specific language impairment. *Journal of Speech, Language, and Hearing Research, 40,* 62–74.

Paul, R., & Alforde, S. (1993). Grammatical morpheme acquisition in 4-year-olds with normal, impaired, and late-developing language. *Journal of Speech and Hearing Research, 36,* 1271–1275.

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.

Scobbie, J. M. (1998). Interactions between the acquisition of phonetics and phonology. In C. Gruber, D. Higgins, K. Olson, & T. Wysocki (Eds.), *Papers from the 34th Annual Regional Meeting of the Chicago Linguistic Society, Volume II: The Panels* (pp. 343–358). Chicago, IL: Chicago Linguistics Society.

Smit, A. B. (1993). Phonologic error distributions in the Iowa-Nebraska articulation norms project: Consonant singletons. *Journal of Speech and Hearing Research, 36,* 533–547.

Smith, C. L. (1997). The devoicing of /z/ in American English: Effects of local and prosodic context. *Journal of Phonetics, 25,* 471–500.

Song, J. Y., Demuth, K., Shattuck-Hufnagel, S., & Ménard, L. (2013). *The effects of coarticulation and morphological complexity on the production of English coda clusters: Acoustic and articulatory evidence from 2-year-olds and adults.* Manuscript submitted for publication.

Song, J. Y., 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.

Stelmachowicz, P. G., Pittman, A. L., Hoover, B. M., Lewis, D. E., & Moeller, M. P. (2004). The importance of high-frequency audibility in the speech and language development of children with hearing loss. *Archives of Otolaryngology—Head & Neck Surgery, 130,* 556–562.

Stevens, K. N. (2002). Toward a model for lexical access based on acoustic landmarks and distinctive features. *The Journal of the Acoustical Society of America, 111,* 1872–1891.

Stevens, K. N., & Keyser, S. J. (2010). Quantal theory, enhancement and overlap. *Journal of Phonetics, 38,* 10–19.

Sundara, M., Demuth, K., & Kuhl, P. (2011). Sentence-position effects on children's perception and production of English 3rd person singular *-s*. *Journal of Speech, Language, and Hearing Research, 54,* 55–71.

Swanson, L. A., & Leonard, L. B. (1994). Duration of function-word vowels in mothers' speech to young children. *Journal of Speech and Hearing Research, 37,* 1394–1405.

Swanson, L. A., Leonard, L. B., & Gandour, J. (1992). Vowel duration in mothers' speech to young children. *Journal of Speech and Hearing Research, 35,* 617–625.

Theodore, R., Demuth, K., & Shattuck-Hufnagel, S. (2010, December 14–16). An acoustic examination of the effects of word frequency and utterance position on 2-year-olds' production of 3rd person singular *-s*. In M. Tabain, J. Fletcher, D. Grayden, J. Hajek, & A. Butcher (Eds.), *Proceedings of the 13th Australasian Conference on Speech Science and Technology, Melbourne* (pp. 158–161). Adelaide, Australia: Causal Productions.

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

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

Tomas, E., Demuth, K., & Smith-Lock, K. (2012, April 12–15). *Phonological complexity and treatment effects on the use of the possessive morpheme by children with SLI*. Poster presented at the 39th Australasian Experimental Psychology Conference (EPC), The University of New South Wales, Sydney, Australia.

Walsh, T., & Parker, F. (1983). The duration of morphemic and non-morphemic /s/ in English. *Journal of Phonetics, 11,* 201–206.

Yuen, I., Demuth, K., & Johnson, M. (2011). Prosodic structure in child speech planning and production. *Proceedings from the 17th International Congress of Phonetic Sciences* (ICPhS XVII; pp. 2248–2251). Hong Kong.

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