Word-minimality, Epenthesis and Coda Licensing in the Early Acquisition of English

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Key words

codas

epenthesis

minimal words

prosodic licensing

Abstract

Many languages exhibit constraints on prosodic words, where lexical items must be composed of at least two moras of structure, or a binary foot. Demuth and Fee (1995) proposed that children demonstrate early sensitivity to word-minimality effects, exhibiting a period of vowel lengthening or vowel epenthesis if coda consonants cannot be produced. This paper evaluates this proposal by examining the development of word-final coda consonants in the spontaneous speech of four English-speaking children between the ages of one and two. Although there was no evidence of vowel lengthening, coda consonants were more accurately produced in monosyllabic target words with monomoriac vowels, suggesting earlier use of coda consonants in contexts where they can be prosodified as part of a bimoraic foot. One child also showed extensive use of vowel epenthesis and coda consonant aspiration concurrent with the production of codas. However, we show that this was due to the articulatory challenges of producing complex syllable structures rather than an attempt to produce well-formed minimal words. These results suggest that learners of English may exhibit an early awareness of moraic structure at the level of the syllable, but that language-specific constraints regarding word-minimality may be acquired later than originally thought.

1 Introduction

Languages differ in the constraints they place on syllable and word structures. Many languages allow only simple CV syllable structures, with an onset consonant and a vowel nucleus (e.g., Sesotho *sekolo* ‘school’). Other languages, such as English, permit much more complex syllable structures, with onset and coda clusters (e.g., CCVCC—*stamp*) (cf. Hammond, 1999). Languages also differ in the word shapes

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they permit, with many showing limitations on prosodic word structure. Languages like English and the southern Bantu language Sesotho both require well-formed prosodic words to contain at least two moras (μμ) of prosodic structure. That is, open class lexical items in these languages must be minimally composed of a binary foot ($[\mu\mu]_{Ft/Pw}$). Thus, the shortest possible prosodic word in English must contain a “heavy” (bimoraic) syllable with a coda consonant (e.g., *tin*; Fig. 1a), or a bimoraic (tense) vowel (e.g., *tea*) or diphthong (e.g., *tie*) (Fig. 1c). Since the syllable rhyme is typically thought to contain no more than two moras of structure, the coda consonant in a word with a bimoraic vowel or diphthong does not contribute a mora to the prosodic structure (e.g., *teen*; Fig. 1b) (cf., Hyman, 1985). All of these constitute well-formed open class prosodic words of English, containing two moras of structure, or a binary foot. In contrast, words containing only one mora of structure (a light syllable with a monomoraic (lax) vowel) can only function as a closed class grammatical function item in English (e.g., *the*; Fig. 1d). An open class lexical item in English containing a monomoraic rhyme would be considered subminimal, or prosodically ill-formed.

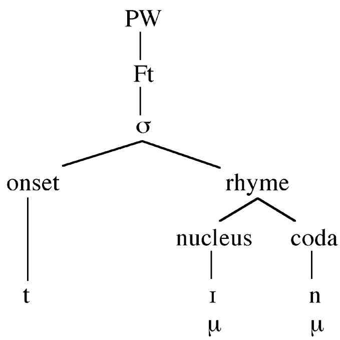
Similar word-minimality restrictions are found in Sesotho. That is, well-formed open class lexical items must consist of a binary foot. However, due to the fact that Sesotho only permits monomoraic CV syllables (Sesotho does not have coda consonants, tense vowels or diphthongs), a minimal word in Sesotho must contain at least two syllables, or be composed of a disyllabic foot, just as in the English word *kitty* (Fig. 1e). If a lexical item happens to contain only one mora of structure, Sesotho employs a process of moraic adjustment, epenthesizing an initial or final vowel to ensure word minimality (e.g., **ja* → *eja* ~ *jaa* ‘eat!’) (Doke & Mofokeng, 1985; see Broselow (1995) for discussion of similar processes in other languages). In contrast, languages like French permit open class lexical items containing only one mora of structure (e.g., *lait* /lɛ/ ‘milk’, *eau* /o/ ‘water’). One of the questions, then, is how and when children become aware of these language-specific word-minimality constraints, and how this plays a role in shaping the structure of their early words (Demuth, 1996).

The purpose of this paper was therefore to examine the early stages of English prosodic word development in order to better understand how language-specific constraints on syllable and prosodic word structures are learned. We focused on the early acquisition of English word-final consonants in monosyllabic words, where it has been proposed that early stages of acquisition will exhibit a brief period of subminimal (monomoraic) CV outputs, followed by the production of minimal words, or binary feet (Demuth, 1995; Demuth & Fee, 1995; Fee, 1995, 1996). We compare this with the acquisition of word-final consonants in disyllabic words. It is predicted that, although early attempts at words like *cat* may initially be produced as CV subminimal words, children will quickly learn that open class lexical items in English must contain at least two moras of structure, and will exhibit adjustment processes such as vowel lengthening or epenthesis if coda consonants cannot yet be produced. Such a developmental trajectory would suggest early awareness of English word-minimality effects. However, we predict that no such processes should be found in disyllabic words, which already constitute a binary foot.

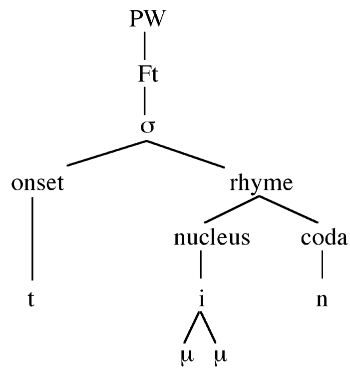
Figure 1

Prosodic structure of different lexical items

a) Lexical item *tin*

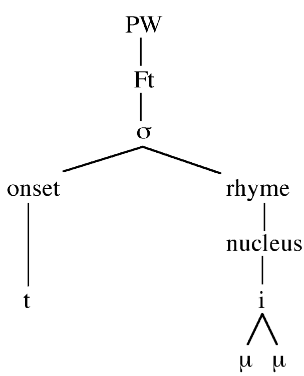


b) Lexical item *teen*

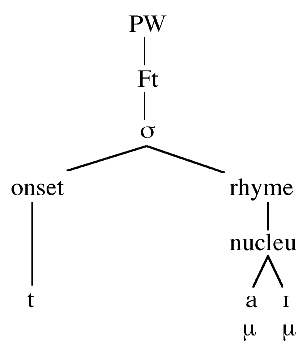


c) Lexical items (i) *tea* and (ii) *tie*

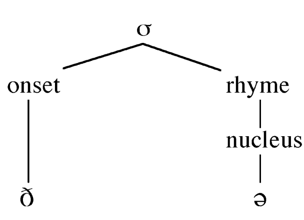
i.



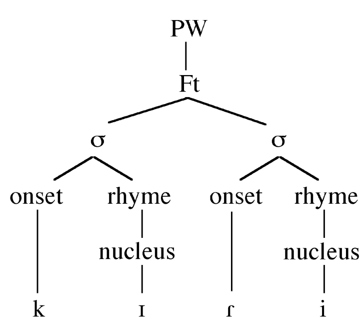
ii.



d) Grammatical function item *the*



e) Lexical item *kitty*



English does not have a contrast between long and short vowels like that found in languages like Finnish. Rather, it has a lax/tense distinction, where /ɪ, ɛ, æ, ʌ, ɝ, ʊ/ are monomoraic vowels, and /i, e, ɑ, o, ɔ, u/ are bimoraic vowels (cf. Ladefoged, 1993). This means that errors in the number of moras a vowel contains will manifest themselves in terms of a change in vowel quality in English. In the following discussion we will therefore refer to changes between monomoraic vowels and bimoraic vowels/dipthongs as changes in moraic content.

There are several reports of children who produce coda consonants in their first words, never going through a subminimal CV word stage of development (e.g., Salidis & Johnson, 1997; Stemberger, 1992). Other children show variability in the structure of their early words, sometimes producing codas and sometimes not (e.g., Fee, 1995; Kirk & Demuth, 2006; Vihman, 1996). For example, Weismer (1984) and Weismer, Dinnsen, and Elbert (1981) provide instrumental measures of compensatory vowel lengthening in the speech of several children with phonological delay, and similar results are documented for children who devoice final obstruents (Catts & Jensen, 1983; Smit & Bernthal, 1983; Velten, 1943). Furthermore, Stemberger (1992), in his analysis of his daughter Gwendolyn, noted her change of a monomoraic vowel to a bimoraic vowel when a target coda was omitted. He offers a performance-based motivation for this type of vowel change, proposing the lack of ability to produce certain coda consonants as the reason for variation in output form. This suggests that the child was employing processes of moraic adjustment to preserve syllable/prosodic word structure when a target coda consonant was omitted from her production.

Similar findings come from a longitudinal study of four 1–2-year-old Japanese-speaking children, where Ota (1999) found that coda consonants took some time to be acquired. However, rather than simply omitting these segments, all four children showed evidence of compensatory vowel lengthening, actually lengthening the vowel to two moras. It appears that Japanese learners are keenly attuned to the moraic structure of their language, employing compensatory lengthening as a means of preserving moraic structure when they cannot produce coda consonants.

Fikkert (1994), in a study of 12 Dutch-speaking children's acquisition of stress, proposed that coda consonants were difficult for children to produce, often resulting in word-final epenthesis or coda omission. She also hypothesized that epenthesis occurred due to an early preference for disyllabic trochaic feet. Vihman and Velleman (1989) also report extensive use of word-final epenthesis by the English-speaking child Molly between 1;1.15 and 1;3.24, primarily in words with nasal codas. They suggest that this is due to the child's experimentation with language, where CVCV word "recipes" are used for several months. In contrast, Demuth and Fee (1995) suggest that if children cannot produce a binary foot by employing the use of a coda, adjustment processes, such as compensatory vowel lengthening and word-final vowel epenthesis, will be used to meet word minimality constraints.

Kehoe and Stoel-Gammon (2001) address some of these issues in a semilongitudinal, cross-sectional study of children between the ages of 1;3–2;0. The purpose of the study was specifically to test the possibility that there might be changes from a monomoraic to a bimoraic vowel in cases of omitted codas. Interestingly, they found few such vowel change errors. However, they did find that coda consonants appear earlier in monosyllabic words containing monomoraic rather than a bimoraic vowels or diphthongs. Thus, it appears that coda consonants are incorporated into children's word productions earlier if the resulting prosodic word contains only a bimoraic foot, such as that illustrated in Figure 1a.

The lack of vowel changes for moraic adjustment purposes reported by Kehoe and Stoel-Gammon (2001) is interesting for several reasons. Given the high frequency of coda consonants in English, and language learners' tendency to produce higher-frequency prosodic structures earlier than lower-frequency structures (e.g., Levelt, Schiller, & Levelt, 2000; Roark & Demuth, 2000), it is possible that English coda consonants may often be acquired before children become aware of word-minimality effects. This suggests that we might be more likely to find moraic adjustment processes of vowel change, compensatory vowel lengthening, or epenthesis in the productions of children who show a delay in the acquisition of coda consonants, or in those languages with a lower frequency of coda consonants overall, where coda acquisition is more protracted.

The frequency of coda consonants is much lower in Spanish and French (25% of syllables) than it is in English (60% of syllables) (Delattre, 1965; Roark & Demuth, 2000). However, Lleó (1997, 1998, 2001) finds no evidence of moraic adjustment processes in her longitudinal study of three Spanish-speaking children, despite the fact that coda consonants were still being acquired at 2;3. This may be due to the fact that most words in Spanish are two or three syllables long, and that the deletion of word-final codas has little impact on prosodic word structure. Alternatively, Spanish coda consonants may be acquired later overall because many occur in unstressed syllables (cf. Kirk & Demuth, 2006, and Lleó, 2003, for discussion).

The situation is somewhat different in French, where subminimal words constitute 20% of the open class lexical items found in child-directed speech. In the longitudinal study of a French-speaking child's early productions, Demuth and Johnson (2003) found that target CVC words initially surfaced as CV, and were then reduplicated as CVCV. However, the child then selectively truncated these (as well as some disyllabic target words) to CV, producing subminimal words. This highly unusual developmental path was not predicted by the theory of prosodic development, where children's prosodic word structures are expected to increase in complexity over time (Demuth, 1996). Demuth and Johnson (2003) showed that the French findings could be explained by appealing to interactions between segmental and prosodic constraints. However, they also argued that subminimal CV words, which make up a significant portion of the French lexicon, must be prosodically licensed by a mature grammar of French. Thus, truncation to subminimal words in a language like French does not violate the general constraints on prosodic word structure in this language. In contrast, truncating open class lexical items to monomoraic CV form does not result in a well-formed open class word of English (though see Goad & Buckley, 2005).

In sum, the different shapes of children's early word productions across languages, and the truncation and moraic adjustment processes found, suggest an early sensitivity to the prosodic word structure in the target language. Thus, we might expect young English learners to quickly progress from CV subminimal word productions to prosodic word structures containing a binary foot, employing moraic adjustment processes as needed. However, there have been few studies specifically addressing these issues in English, and those that have (e.g., Kehoe & Stoel-Gammon, 2001) have used cross-sectional semilongitudinal data from several children at certain points in time, perhaps missing critical stages of rapid phonological development. What is needed is a longitudinal, quantitative study of several children that examines word productions from the onset of first words until coda consonants have been acquired. In this way it will be possible to more fully evaluate the development of prosodic word structures in English, and determine when and how children come to realize that these must be composed of binary feet.

The goal of this study was therefore to evaluate the lower bounds on children's early word productions and how these developed over time. In particular, we wanted to assess the various strategies used to produce monosyllabic target words containing a word-final coda consonant, and determine whether children would show moraic changes in vowels, or epenthesis/reduplication en route to acquiring words of this prosodic structure. This would provide evidence of possible sensitivity to the word-minimality restrictions of English. If a child cannot produce coda consonants and is not aware of word-minimality effects, this should result in the production of subminimal CV truncations for words with monomoraic vowels (e.g., *cat* [ˈkæ]), but well-formed binary feet/minimal words for targets containing bimoraic vowels or diphthongs (e.g., *boat* [ˈbo], *side* [ˈsɑɪ]). However, we would predict no moraic adjustment in disyllabic words where codas are omitted, since these already constitute a well-formed binary foot (Fig. 1e).

2 The study

In this study we examine the development of coda consonants in monosyllabic and disyllabic words in four children longitudinally, from the onset of their first words until they reach over 80% production of coda consonants. Monosyllabic words with a final consonant are common in English, making up around 80% of the word-tokens children typically hear and produce (Roark & Demuth, 2000). After discussion of the database used and the participants, we investigate the overall patterns of word-final coda production, and then examine the acquisition of coda consonants as a function of vowel type (monomoraic vs. bimoraic), number of syllables in the word (monosyllabic vs. disyllabic), epenthetic processes, and the segmental content of the codas produced.

2.1 *Data collection and transcription procedures*

The data were drawn from a subset of recordings from the Providence Corpus, a longitudinal corpus of spontaneous child-adult speech interactions of six children from southern New England between approximately one and three years. The four children examined here were all monolingual speakers of Standard American English, with no noticeable regional accent. Digital audio/video recordings took place in the child's home for approximately one hour every two weeks, commencing with the onset of children's first words. In most cases a research assistant came to set up the recording equipment and then left, encouraging naturalistic spontaneous speech interactions between parent and child. The children and their parents (usually the mother) wore a wireless Azden WLT/PRO VHF lavalier microphone pinned to the collar. The child's radio transmitter was stored in a child-sized backpack. The radio receiver was attached to the top of a small Panasonic PV-DV601D-K Mini digital video recorder placed on a tripod nearby. Although parent and child could move freely about, the video information was useful in determining the context of what was being discussed, including possible target words.

At the completion of each session the digital audio/video recordings were downloaded onto a computer, and both adult and child speech were orthographically transcribed using CHAT conventions (cf. MacWhinney, 2000). The child data were then also transcribed in broad phonetic transcription. The child's target words were determined using a combination of visual information from the video, linguistic context, and phonetic match (see Vihman & McCune (1994) for discussion of similar procedures). Any targets that were not clear (indicated in the transcripts with yy) were excluded from our analysis. Only those target words for which the coder had at least a 95% confidence level were included in the study. Ten percent of the child data from each recording session were retranscribed by a second transcriber. Reliability between the two transcribers averaged 84%. Since consonant voicing is typically acquired late and is difficult to reliably transcribe (cf. Stoel-Gammon & Buder, 1999), differences in voicing were not counted as errors.

2.2
Participants

The participants were four normally developing children with no clinically diagnosed neurological, motor control, language or hearing deficits. All had enrolled with their parents in a two-year longitudinal study of phonological and morphological development (The Providence Corpus). Recording began around one year or once the parent reported that the child was producing approximately four words. Two of the participants were girls (Naima and Lily) and two were boys (Ethan and William). Two of the children were precocious, producing their first words around 11 months (Naima and Ethan). Both children surpassed 25 word types per half hour of data collection (indicative of a production vocabulary of 50 words (cf. Vihman, 1996) at 1;1.11 and 1;0.23 respectively. Both also performed in the 99th percentile on vocabulary development as measured using the long form of the MacArthur CDI (Communicative Developmental Inventory) at 1;5.1 year and 1;6.21 respectively. The other two children were slower to develop. Lily initially produced very little, scoring at only the 5th percentile on the MacArthur CDI when she was 1;6.30, and only reaching 25 word-types (actually 60) per half hour session at 1;7,20. Many of her early productions were CVCV targets (e.g., *daddy, doggie, daisy, baby, Lisa, kitty, teddy*). She then showed rapid development around 1;8 months, including a substantial number of CVC targets for the first time. William's mother reported that he used very few words before 1;4. However, during the first recording session at 1;4.10 he already had 36 word types for the first half hour, and scored at the 53rd percentile on the MacArthur CDI at 1;8.13. Thus, the data set examined here shows a range of developmental trajectories.

The children's ages and MLU's (mean length of utterance in words) are provided in Table 1.[1]

Table 1

Participants' ages and MLU (Mean Length of Utterance in words)

	Child and MLU			
Age	*Naima*	*Ethan*	*Lily*	*William*
0;11	1.08	1.04	--	--
1;0	1.13	1.46	--	--
1;1	1.34	1.07	1.01	--
1;2	1.45	1.10	1.27	--
1;3	1.64	1.45	1.02	--
1;4	1.87	1.62	1.04	1.26
1;5	2.82	1.87	1.08	--
1;6	--	1.88	1.22	1.26
1;7	--	--	1.06	1.30
1;8	--	--	1.27	1.46
1;9	--	--	1.46	1.45
1;10	--	--	--	1.48
1;11	--	--	--	1.27
2;0	--	--	--	1.58
2;1	--	--	--	1.68

2.3
General data coding procedures

Since the goal of this study was to examine the possibility of word-minimality effects in children's early prosodic words, several analyses were conducted. The first was an evaluation of coda consonant production in general. This was followed by a more in-depth comparison of the acquisition of monomoraic and bimoraic vowels, the acquisition of coda consonants as a function of vowel type, epenthetic processes, and the segmental content of the codas produced. All analyses were based on the initial extraction from each of the children's corpora of all monosyllabic and disyllabic target words containing singleton codas. These included words with monomoraic vowels (e.g., *sip*), bimoraic vowels (e.g., *sheep*) and diphthongs (e.g., *side*), and the same for the final syllable of disyllabic words. It also included target words with no onset consonant (e.g., *up*, *off*) and target words with an initial consonant cluster (e.g., *step*).

1 Naima had three sessions at 1;3 years, four sessions at 1;4 years, but only one at 1;5 years. The last session at 1;4 years, recorded when she was 1;4.25, was therefore added to the data under 1;5 years. Data collection for William began late, and no data were collected during the month when he was 1;5.

As in Kehoe and Stoel-Gammon (2001), vowels were coded according to the conventions in Ladefoged (1993), where /ɪ, ɛ, æ, ʌ, ɝ, ʊ/ are short/lax (monomoraic) vowels, and / i, e, ɑ, o, ɔ, u / are long/tense (bimoraic) vowels. The analysis of segmental effects considered coda consonants by sonority class according to the following sonority hierarchy, where stops are the least sonorant, and glides are the most sonorant: Stops > Affricates > Fricatives > Nasals > Liquids > Glides (cf. Ladefoged, 1993). Liquid consonants are often problematic for young English-speaking children, and are typically acquired very late (cf. Kehoe & Stoel-Gammon, 2001; Smit, 1993). Most of the children in this study produced no target liquid codas until the last session, only William averaging around 5%. Prior to that point both /l/ and /r/ tended to be vocalized in coda position, often resulting in a second schwa syllable for target /r/ (e.g., William 2;1.23 *square* ['skwɛ.ə]). By the end of the time period examined here, only William produced significant numbers of liquid codas in monosyllabic words (Naima 0%, Ethan 17%, Lily 11.5%, William 30%). We therefore excluded consideration of liquids from most of our analyses, leaving this for future research. Affricates are also often acquired late, but there were few tokens overall. These were grouped with fricatives. In the initial analyses a coda consonant was considered as "produced" if it was identical to the target (e.g., *dog* ['dɑg]), had a voicing change (*dog* ['dɑk]), or was realized as a different segment with a change of either place or sonority (*dog* ['dɑp], *clap* ['klæf]), though these again were few. The total number of monosyllabic word types and tokens (including liquids) analyzed per child are presented in Table 2.

Table 2

Total Types/Tokens of monosyllabic words with word-final consonants analyzed

	Naima	***Ethan***	***Lily***	***William***
Age	*Types/Tokens*	*Types/Tokens*	*Types/Tokens*	*Types/Tokens*
0;11	4/25	5/8	--	--
1;0	17/38	20/133	--	--
1;1	19/45	31/131	7/15	--
1;2	25/69	55/217	4/6	--
1;3	118/611	61/248	0/0	--
1;4	167/875	139/490	1/2	41/130
1;5	129/533	51/194	4/7	--
1;6	--	133/522	8/31	42/133
1;7	--	--	36/105	64/227
1;8	--	--	105/304	103/350
1;9	--	--	116/254	79/202
1;10	--	--	--	88/251
1;11	--	--	--	29/122
2;0	--	--	--	74/261
2;1	--	--	--	67/291
Total	479/2196	495/1943	281/724	587/1967

Disyllabic words were first analyzed for syllable preservation, truncated forms being discarded. As shown in Table 3, there were many more trochaic than iambic target words, and truncations were primarily of iambs. This is in keeping with much of the literature showing a tendency for English-speaking children below the age of two to truncate word-initial unstressed syllables in words like *giraffe* (cf. Pater, 1997). Truncated forms were discarded from our analysis, since we wanted to focus on word-final coda production in disyllabic productions. The total number of nontruncated disyllabic types and tokens analyzed per child (including liquids) is presented in Table 4.

Table 3

Number (percent) truncated disyllabic (iambic and trochaic) words produced

	Naima		***Ethan***		***Lily***		***William***	
	Number	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
Iambs	26/36	(72)	31/43	(72)	0/0	(0)	32/63	(51)
Trochees	51/653	(8)	40/584	(7)	0/69	(0)	16/330	(5)

Table 4

Total Types/Tokens of nontruncated disyllabic (trochaic and iambic) words with word-final consonants analyzed

	Naima	***Ethan***	***Lily***	***William***
Age	*Types/Tokens*	*Types/Tokens*	*Types/Tokens*	*Types/Tokens*
0;11	0/0	--	--	--
1;0	5/14	2/2	--	--
1;1	4/23	5/9	0/0	--
1;2	8/35	19/53	0/0	--
1;3	26/121	21/80	0/0	--
1;4	50/190	48/149	0/0	3/3
1;5	44/229	15/47	1/1	--
1;6	--	58/215	0/0	8/9
1;7	--	--	1/2	8/22
1;8	--	--	7/12	28/68
1;9	--	--	22/54	21/38
1;10	--	--	--	20/60
1;11	--	--	--	9/22
2;0	--	--	--	22/36
2;1	--	--	--	11/56
Total	137/612	168/556	31/69	130/314

3 Results

3.1
Coda production in monosyllabic and disyllabic words

The overall development of coda consonants in monosyllabic words (excluding liquids) is shown in Table 5. All the children except William show a relatively abrupt increase in the percent of codas produced over a relatively short period of time, corresponding closely to the point where they had a productive vocabulary of 50 words. Thus, consistent with other studies of English, these four children show relatively early acquisition of coda consonants (e.g., Kehoe & Stoel-Gammon, 2001; Salidis & Johnson, 1997). This is to be expected if children are sensitive to the fact that the majority of syllables in English contain a syllable-final consonant.

Table 5

Number (percent) of nonliquid word-final codas produced in monosyllabic words

	Naima		*Ethan*		*Lily*		*William*	
Age	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
0;11	1/24	(4)	0/4	(0)	--	--	--	--
1;0	1/28	(4)	25/47	(53)	--	--	--	--
1;1	3/21	(14)	31/74	(42)	4/11	(36)	--	--
1;2	25/60	(42)	139/173	(80)	1/1	(100)	--	--
1;3	259/496	(52)	138/179	(77)	0/0		--	--
1;4	637/792	(80)	369/420	(88)	0/0	(0)	59/108	(55)
1;5	423/479	(88)	118/123	(96)	1/4	(25)	--	--
1;6	--	--	361/387	(93)	13/29	(45)	78/121	(65)
1;7	--	--	--	--	71/89	(80)	158/190	(83)
1;8	--	--	--	--	270/285	(95)	235/295	(80)
1;9	--	--	--	--	218/228	(96)	144/171	(84)
1;10	--	--	--	--	--	--	194/213	(91)
1;11	--	--	--	--	--	--	83/100	(83)
2;0	--	--	--	--	--	--	166/216	(77)
2;1	--	--	--	--	--	--	192/221	(87)
Total	1349/1900	(71)	1181/1407	(84)	578/647	(89)	1309/1635	(80)

What about coda production in disyllabic words? Coda preservation in disyllabic words is not needed for word-minimality, since disyllabic words are already composed of a disyllabic foot. Therefore, if we were to find vowel changes or epenthesis in disyllables, this would show that these processes are not due to word-minimality effects. Kirk and Demuth (2006) show that two-year-olds tend to produce fewer word-final coda consonants in disyllabic novel words, even when controlling for stress. We then also expected later acquisition of codas in disyllables. Most of the disyllabic words produced as disyllables in this study were trochees, with a word-final unstressed syllable. We therefore expected children to produce word-final coda consonants later in disyllables than in monosyllables, which they did; all of the children showed a delay of a few months in producing word-final coda consonants in disyllabic words. However, by the end of the study all the children were producing over 80% of word-final coda consonants in disyllables as well. This is shown in Table 6.

Table 6

Number (percent) of nonliquid word-final codas produced in disyllabic words

	Naima		***Ethan***		***Lily***		***William***	
Age	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
0;11	0/0		0/0		--	--	--	--
1;0	1/8	(13)	0/1	(0)	--	--	--	--
1;1	0/2	(0)	0/5	(0)	0/0		--	--
1;2	0/16	(0)	10/30	(33)	0/0		--	--
1;3	21/36	(58)	36/70	(51)	0/0		--	--
1;4	63/87	(72)	69/116	(60)	0/0		0/2	(0)
1;5	133/144	(92)	29/34	(85)	0/1	(0)	--	--
1;6	--	--	82/100	(82)	0/0		5/9	(56)
1;7	--	--	--	--	0/2	(0)	16/20	(80)
1;8	--	--	--	--	11/12	(92)	48/60	(80)
1;9	--	--	--	--	47/53	(87)	27/32	(84)
1;10	--	--	--	--	--	--	30/41	(73)
1;11	--	--	--	--	--	--	18/21	(86)
2;0	--	--	--	--	--	--	28/30	(93)
2;1	--	--	--	--	--	--	43/46	(94)
Total	218/293	(74)	226/356	(64)	58/68	(85)	215/261	(82)

As expected, codas were more likely to be produced in disyllabic words ending in a stressed syllable (iambs), at least for Naima and Ethan (though the number of nontruncated iambs is few). Lily had no iambic target words ending in a coda consonant, and William showed similar performance on both target types. All three children who attempted iambs showed a few cases of stress shift to the first syllable. This is shown in Table 7.

Table 7

Number (percent) word-final nonliquid coda consonants produced as a function of stress (trochaic vs. iambic words) on disyllabic target words

	Naima		*Ethan*		*Lily*		*William*	
	Number	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
Trochaic	209/283	(74)	214/344	(62)	58/68	(85)	191/230	(83)
Iambic	8/8	(100)	8/8	(100)	0/0	--	21/26	(81)
Iambic→Trochaic	1/2	(50)	4/4	(100)			3/5	(60)

The participants in this study thus exhibit rapid acquisition of word-final coda consonants in both monosyllabic and disyllabic words. However, all participants also showed an early period of development where they produced many words with no codas. In the following section we examine these productions more closely in terms of the types of targets attempted, and evaluate the possibility that moraic adjustment strategies may have been used to approximate minimal words, or binary feet, when coda consonants were not produced in monosyllabic targets with short vowels.

3.2
Vowel changes and the prosodic licensing of codas

In order to address the possibility that children conserve prosodic structure in order to meet word-minimality constraints it is necessary to examine children's production of target vowels. Demuth and Fee (1995) had originally proposed that learning vowel length contrasts in English took some time to master, leading to the inconsistent production of vowels as either monomoraic or bimoraic. English vowels can vary greatly in duration depending on the context in which they are produced. We therefore did not examine the possibility of compensatory vowel lengthening processes, where monomoraic vowels might be lengthened to approximate bimoraic structure (CV:) when coda consonants were not produced. This is obviously an area for further (acoustic) research, but fell beyond the scope of the present study. Rather, we followed Kehoe and Stoel-Gammon (2001) in examining perceptual transcriptions of the data, where vowels were counted as correctly produced if a monomoraic vowel was produced as monomoraic, even if the quality of the vowel was modified. Likewise, bimoraic vowels/diphthongs were counted as correctly produced if they were realized as a bimoraic. If children showed a tendency to change monomoraic vowels to bimoraic vowels when target codas were not produced, this would provide some evidence that children were employing moraic adjustment, possibly to meet word-minimality requirements. However, if children consistently produced target vowels regardless of whether target codas were realized, producing subminimal monomoraic CV forms, this would indicate that children may not yet be aware of the phonological constraints on English prosodic words. As in Kehoe and Stoel-Gammon (2001), vowel types were coded according to the conventions in Ladefoged (1993), where /i, e, ɑ, o, ɔ, u/ are long/tense (bimoraic) vowels, and /ɪ, ɛ, æ, ʌ, ɝ, ʊ/ are short/lax (monomoraic) vowels.

Although William's mother had a distinction between low back vowels /ɑ/ and /ɔ/, the other parents did not.

Recall that Kehoe and Stoel-Gammon (2001) found that the children in their study accurately produced monomoraic and bimoraic vowels very early, contra proposals by Demuth and Fee (1995) that the moraic status of vowels took time to master. However, Kehoe and Stoel-Gammon (2001) also found earlier acquisition of coda consonants in monosyllabic words with monomoraic vowels, suggesting that codas are prosodically licensed earlier in when they constitute the second mora of a bimoraic rhyme. Most of the words produced with no coda resulted of target-like vowels. However, if children could not accurately produce vowels, we might expect bimoraic vowels and diphthongs to occasionally be produced as monomoraic (e.g., *down* ['dʌ]), and monomoraic vowels to be occasionally be produced as bimoraic (*bug* ['bu]). Alternatively, if children have an early awareness of moraic structure, and can accurately produce both monomoraic and bimoraic vowels, we would expect to find changes in vowel type only in monosyllabic words with monomoraic vowel targets prior to the consistent production of coda consonants.

For this analysis all monosyllabic target words with word-final consonants were analyzed for vowel type accuracy (monomoraic vs. bimoraic), irrespective of whether these words were produced with a following coda consonant or not. As expected, most of the vowel type errors occurred in the earliest sessions. However, the overall accuracy on the production of vowel types was high, at over 85% for all participants. This is shown in Table 8.

Table 8

Number (percent) of vowels realized as target appropriate (monomoraic or bimoraic) in monosyllabic words with target coda consonants

	Naima		***Ethan***		***Lily***		***William***	
	Number	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
Monomoraic V	939/950	(99)	831/879	(95)	311/312	(100)	841/874	(96)
Bimoraic V	824/950	(87)	473/528	(90)	321/335	(96)	696/761	(92)
Total	1763/1900	(93)	1304/1407	(93)	632/647	(98)	1537/1635	(94)

The results show that accuracy in production of vowel length was high for all the participants, and for both monomoraic vowels and bimoraic vowels/diphthongs. This is consistent with the cross-sectional findings by Kehoe and Stoel-Gammon (2001). However, a chi square analysis showed that two of the children exhibited greater accuracy with monomoraic vowels than with bimoraic vowels/diphthongs (Naima $\chi^2 = 6.45$, $df = 1$, $p = .01$; William $\chi^2 = 10.62$, $df = 1$, $p = .001$). Diphthongs proved especially challenging for Naima, with only 66% produced with appropriate vowel length as compared to Ethan (83%), Lily (91%), and William (80%).

If children have an early awareness of moraic structure, and can accurately produce monomoraic/bimoraic vowels, we would expect to find vowel changes only in monosyllabic words with monomoraic vowel targets prior to coda consonants being reliably produced. However, even when codas were not produced, none of the children in this study used moraic adjustment of vowels as a strategy for preserving moraic structure/binary feet, though two of the children were more accurate at producing target vowels in these contexts than the others. These results are shown in Table 9.

Table 9

Number (percent) of monomoraic vowel targets produced as bimoraic in monosyllabic words where no coda was produced

Naima		***Ethan***		***Lily***		***William***	
Number	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
11/250	(4)	34/113	(30)	1/18	(6)	33/148	(22)

William produced *what* as ['wɑ] 18 times at 1;6.3 years, and Ethan produced *big* as ['bi] or ['pi] a total of 21 times at 1;3.15 and 1;4.0 years. This accounted for both children's higher rate of monomoraic vowels being produced as bimoraic when no coda was produced. Lily had few vowel errors overall, and only one on monomoraic vowels produced with no coda. Naima sometimes increased the duration of the target vowel when she omitted a coda consonant (CV:), but since this occurred with words containing both monomoraic and bimoraic vowels (e.g., *cup* ['kʌ] vs. *beach* ['biː] (1;3.12)), it appears that this was not being done to preserve prosodic structure. Sample vowel errors from each of the children are provided in (1).

(1) Sample Vowel Errors

a. Monomoraic Vowels → Bimoraic Vowels

Target Word		*Production*	*Age*	*Child*
lid	/'lɪd/	['li]	1;0.28	Naima
book	/'bʊk/	['buki]	1;2.23	Naima
kiss	/'kɪs/	['kis]	1;3.12	Naima
book	/'bʊk/	['bu]	1;0.23	Ethan
book	/'bʊk/	['bʊd]	1;2.2	Ethan
bat	/'bæt/	['bɑtʰ]	1;2.18	Ethan
fish	/'fɪʃ/	['siʃ]	1;6.28	Lily
book	/'bʊk/	['bɑk]	1;6.28	Lily
sun	/'sʌn/	['sɑ]	1;7.20	Lily
spin	/'spɪn/	['bin]	1;7.7	William
put	/'pʊt/	['pɑ]	2;0.12	William
it	/'ɪt/	['i]	2;0.24	William

b. Bimoraic Vowels → Monomoraic Vowels

Target Word		*Production*	*Age*	*Child*
down	/ˈdaʊn/	[ˈdæ]	0;11.28	Naima
slide	/ˈslaɪd/	[ˈlʌ]	1;2.23	Naima
rice	/ˈraɪs/	[ˈwʌki]	1;2.23	Naima
hot	/ˈhɑt/	[ˈhæt]	1;2.23	Naima
mice	/ˈmaɪs/	[ˈmʌs]	1;3.12	Naima
dog	/ˈdɑg/	[ˈdæ]	1;0.6	Ethan
tock	/ˈtɑk/	[ˈdæ]	1;0.23	Ethan
geese	/ˈgis/	[ˈgʊs]	1;1.7	Ethan
down	/ˈdaʊn/	[ˈdʌn]	1;2.18	Ethan
moon	/ˈmun/	[ˈmʌ]	1;6.9	Lily
dog	/ˈdɑg/	[ˈdʌː]	1;6.9	Lily
brown	/ˈbraʊn/	[ˈbwʌn]	1;6.28	Lily
spoon	/ˈspun/	[ˈpʊn]	1;6.28	Lily
nose	/ˈnoz/	[ˈnʌθ]	1;7.7	William
moon	/ˈmun/	[ˈmʌn]	1;7.7	William
rain	/ˈreɪn/	[ˈrɛ]	1;7.7	William
not	/ˈnɑt/	[ˈnʌ]	1;8.2	William

Thus, although there are some vowel changes, all participants performed above 95% in correctly producing monomoraic vowels as monomoraic (Table 8). This provides strong evidence for the fact that systematic use of vowel change was not employed as a moraic adjustment strategy to meet word-minimality requirements.

We now turn to an examination of coda consonant production as a function of vowel type. We might expect early acquisition of coda consonants in those contexts where codas are prosodically licensed, that is, where they can occur within the rhyme as part of a bimoraic foot. This might also help account for some of the variability in the course of coda acquisition. The results are presented in Table 10.

A comparison of coda production as a function of vowel type shows that all of the children in this study had a tendency to produce coda consonants earlier, and were significantly more accurate overall, in target words containing monomoraic vowels as compared with target words containing bimoraic vowels/diphthongs (Naima $\chi^2 = 6.65$, $df = 1$, $p = .01$; Ethan $\chi^2 = 17.87$, $df = 1$, $p = .000$; Lily $\chi^2 = 15.16$, $df = 1$, $p = .000$; William $\chi^2 = 10.62$, $df = 1$, $p = .001$). This suggests that, although there were no moraic vowel adjustments found in monosyllabic words, codas are produced earlier where they are prosodically licensed as part of a bimoraic foot (i.e., Fig. 1a, rather than Fig. 1b). Note, however, that these findings are also consistent with an input-driven explanation of the data. That is, English does not permit monomoraic vowels in word-final open syllables. Perhaps, children's productions are merely exhibiting distributional aspects

Table 10

Number (percent) of monosyllabic coda consonants produced as a function of vowel type

Monomoraic Vowels

	Naima		*Ethan*		*Lily*		*William*	
Age	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
0;11	0/0		0/3	(0)	--	--	--	--
1;0	0/12	(0)	22/40	(55)	--	--	--	--
1;1	2/7	(29)	22/40	(55)	4/6	(67)	--	--
1;2	15/25	(60)	86/101	(85)	1/1	(100)	--	--
1;3	114/200	(57)	79/98	(81)	0/0		--	--
1;4	365/464	(79)	227/252	(90)	0/0		29/53	(55)
1;5	204/242	(84)	81/84	(96)	1/1	(100)	--	--
1;6			249/261	(95)	10/11	(91)	45/75	(60)
1;7	--	--			52/53	(98)	86/108	(80)
1;8	--	--	--	--	125/135	(93)	113/130	(87)
1;9	--	--	--	--	101/105	(96)	79/89	(89)
1;10	--	--	--	--			100/108	(93)
1;11	--	--	--	--	--	--	65/70	(93)
2;0	--	--	--	--	--	--	97/120	(81)
2;1	--	--	--	--	--	--	112/121	(93)
Total	700/950	(74)	766/879	(87)	294/312	(94)	726/874	(83)

Bimoraic Vowels

	Naima		*Ethan*		*Lily*		*William*	
Age	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
0;11	1/24	(4)	0/1	(0)				
1;0	1/16	(6)	3/7	(43)				
1;1	1/14	(7)	9/34	(27)	0/5	(100)		
1;2	10/35	(29)	53/72	(74)	0/0			
1;3	145/296	(49)	59/81	(73)	0/0			
1;4	272/328	(83)	142/168	(85)	0/0		30/55	(55)
1;5	219/237	(92)	37/39	(95)	0/3	(0)		
1;6			112/126	(89)	3/18	(17)	33/46	(72)
1;7					19/36	(52)	72/82	(88)
1;8					145/150	(97)	122/165	(74)
1;9					117/123	(95)	65/84	(77)
1;10							94/105	(90)
1;11							18/30	(60)
2;0							69/96	(72)
2;1							80/100	(80)
Total	649/950	(68)	415/528	(79)	284/335	(85)	583/761	(77)

of English rather than showing the effects of word-minimality. We turn to this issue in a discussion of coda production in disyllabic words below, where these two possible explanations of children's productions make different predictions: if the same patterns are found in disyllables, this would suggest that these patterns are due to distributional factors. However, if children show no tendency to produce more coda consonants in disyllabic words ending in monomoraic vowels, this would indicate that the tendency found in monosyllabic words might be due to word-minimality effects.

Children's production of vowels at the ends of disyllabic words was less accurate compared with that of monosyllabic words (Naima $\chi^2 = 70.88$, $df = 1$, $p = .000$; Ethan $\chi^2 = 39.43$, $df = 1$, $p = .000$; Lily $\chi^2 = 5.74$, $df = 1$, $p = .017$; William $\chi^2 = 8.13$, $df = 1$, $p = .004$. This is shown in Table 11. This is probably due to the fact that these vowels were mostly in unstressed syllables (cf., Kirk & Demuth (2006)). Furthermore, vowel production accuracy in disyllables no longer showed a significant difference as a function of vowel type for Naima, Lily or William (Naima $\chi^2 = 5.16$, $df = 1$, $p = .023$; Ethan $\chi^2 = 9.44$, $df = 1$, $p = .002$; Lily $\chi^2 = 2.41$, $df = 1$, $p = .121$; William $\chi^2 = 0.011$, $df = 1$, $p = .916$). All the children showed a tendency to produce some monomoraic vowels as bimoraic when no coda was produced (Table 12). Note, however, that this cannot be due to word-minimality constraints, since these disyllabic words already constitute a binary foot. This vowel change might then best be understood as a form of moraic conservation at the level of the syllable. The accuracy of coda production as a function of vowel type in disyllabic words is presented in Table 13. As predicted, coda production in disyllabic words did not differ significantly by vowel type for any of the children except for Naima, who was significantly better at producing coda consonants with bimoraic vowel targets (Naima $\chi^2 = 14.99$, $df = 1$, $p = .000$; Ethan $\chi^2 = 0.49$, $df = 1$, $p = .484$; Lily $\chi^2 = 5.24$, $df = 1$, $p = .022$; William $\chi^2 = 2.03$, $df = 1$, $p = .154$). Note, however, that there are few tokens of disyllabic target words with bimoraic vowels in the early sessions. Thus, Naima's apparent better production of coda consonants with bimoraic vowels in disyllabic words may be due to the fact that these were attempted later, when coda production was already good.

Table 11

Number (percent) of monomoraic and bimoraic vowels/diphthongs produced target appropriately in the final syllable of disyllabic target words

	Naima		***Ethan***		***Lily***		***William***	
	Number	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
Monomoraic V	145/197	(74)	245/309	(79)	42/47	(89)	198/222	(89)
Bimoraic V	82/96	(85)	46/47	(100)	21/21	(100)	35/39	(90)
Total	227/293	(78)	291/356	(82)	63/68	(93)	233/261	(89)

Table 12

Number (percent) of word-final monomoraic vowels produced as bimoraic when no coda was produced in disyllabic target words

Naima		*Ethan*		*Lily*		*William*	
Number	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
33/64	(52)	36/115	(31)	3/10	(30)	12/36	(33)

Table 13

Number (percent) of word-final coda consonants produced as a function of word-final vowel type in disyllabic words

Monomoraic Vowels

	Naima		*Ethan*		*Lily*		*William*	
Age	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
0;11	0/0		0/0		--	--	--	--
1;0	1/8	(13)	0/1	(0)	--	--	--	--
1;1	0/1	(0)	0/5	(0)	0/0		--	--
1;2	0/16	(0)	9/29	(31)	0/0		--	--
1;3	4/13	(31)	36/69	(52)	0/0		--	--
1;4	53/75	(71)	62/104	(60)	0/0		0/2	(2)
1;5	75/84	(89)	26/29	(90)	1/1	(100)	--	--
1;6			61/72	(85)	0/0		3/7	(43)
1;7	--	--			0/2	(0)	12/14	(86)
1;8	--	--	--	--	5/6	(83)	47/54	(87)
1;9	--	--	--	--	32/38	(84)	24/28	(86)
1;10	--	--	--	--			19/29	(66)
1;11	--	--	--	--	--	--	14/17	(82)
2;0	--	--	--	--	--	--	24/26	(92)
2;1	--	--	--	--	--	--	43/45	(96)
Total	133/197	(68)	194/309	(63)	37/47	(79)	186/222	(84)

Bimoraic Vowels

	Naima		*Ethan*		*Lily*		*William*	
Age	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
0;11	0/0		0/0					
1;0	0/0		0/0					
1;1	0/1	(0)	0/0		0/0			
1;2	0/0		1/1	(100)	0/0			
1;3	17/23	(74)	0/1	(0)	0/0			
1;4	10/12	(83)	7/12	(58)	0/0		0/0	
1;5	58/60	(97)	3/5	(60)	0/0			
1;6			21/28	(75)	0/0		2/2	(100)
1;7					0/0		4/6	(67)
1;8					6/6	(100)	1/6	(17)
1;9					15/15	(100)	3/4	(75)
1;10							11/12	(92)
1;11							4/4	(100)
2;0							4/4	(100)
2;1							0/1	(0)
Total	85/96	(87)	32/47	(68)	21/21	(100)	29/39	(74)

The findings in this longitudinal study therefore replicate those of the cross-sectional findings reported in Kehoe and Stoel-Gammon (2001), showing early production accuracy with English vowels in monosyllabic words, and no tendency to change monomoraic vowels into bimoraic vowels when codas are not produced. In addition, we found that codas were produced on average about two months later in disyllabic words. Both factors indicate that, although there is little support for moraic conservation for word-minimality purposes, there is some evidence that codas are produced earlier in prosodically licensed contexts. We therefore suggest that, although bimoraic structure is critical to the well-formedness of open class English prosodic words, it does not appear to have the same status as moraic structure in Japanese, where compensatory vowel lengthening is systematically found when children delete coda consonants (cf. Ota, 1999). These results also differ from findings on the early acquisition of Dutch, where syllables must be minimally and maximally bimoraic, and children appear to be sensitive to these restrictions early in the process of acquisition (Fikkert, 1994) (cf. Grijzenhout & Joppen, 1998, for discussion of related issues in German). This suggests that the prosodic structure of the ambient language may play an important role in determining the form and structure of children's early word productions.

3.3
Word-final epenthesis and aspiration

As discussed above, most of the participants in this study showed rapid acquisition of coda consonants after an initial period of no codas. However, previous studies have also reported cases of vowel epenthesis, in both English (Demuth & Fee, 1995; Fee, 1995) and Dutch (Fikkert, 1994). Reports of epenthesis (or reduplication) are not common, but are typically found early, before 1;6 or 1;8 (e.g., Fee & Ingram, 1982; Matthei, 1989; Schwartz, Leonard, Wilcox, & Folger, 1980; Vihman & Velleman, 1989). Therefore, much is still unknown about why some children epenthesize early words ending in a consonant. Demuth and Fee (1995), Fee (1995) and Demuth (1995) argue that vowel epenthesis may be used as a strategy for preserving word-minimality before coda consonants can be produced. Similarly, Bernhardt and Stemberger (1998, p. 378) suggest that epenthesis may be used not to save the coda, but to save its timing unit. In contrast, Fikkert (1994) argues that vowel epenthesis in her Dutch data demonstrates children's preference for disyllabic (rather than monosyllabic), trochaic feet. In this study Lily's early productions included primarily CVCV targets for several months, and Demuth and Johnson (2003) report early CVCV reduplicated targets in their study of one French-speaking child, suggesting a possible selection of CVCV forms in early child speech. However, Demuth and Johnson (2003) also found later reduplication of CVC targets at the same time that CV subminimal target words were correctly produced as CV, never being reduplicated. If there had been a preference for disyllabic feet we might have expected subminimal target words in French to also reduplicate, epenthesize, or show evidence of compensatory vowel lengthening. Perhaps some children show this as a very early preference that quickly disappears (cf. Goad & Buckley's (2005) discussion of Canadian French-speaking child Clara who showed few cases of reduplication on CV words (CV → CVCV), but extensive use of compensatory vowel lengthening (CV → CV:) from 1;0,28 – 1;5,5).

Most of the participants in the present study showed only the occasional use of epenthesis, and little use of reduplication. However, Naima showed an extended period of epenthesis between the ages of 1;2 and 1;4 (e.g., *book* ['bʊki], *block* ['bɔbɔ], *frog* ['fɑgə], *clown* ['klʌnə]). This also occurred at a point in development where Naima was producing codas. Thus, during the month when she was 1;3 years 52% of Naima's monosyllabic CVC target word productions contained codas (CVC), 14% contained no coda (CV), and 34% exhibit vowel epenthesis (CVCV). This is shown in Table 14. Significantly, only 1% of disyllables exhibited epenthesis, perhaps due to an aversion to producing three-syllable words. This is show in Table 15.

An exhaustive list of Naima's monosyllabic CVC word targets and the forms in which they surfaced at 1;3.12 is provided in the Appendix. These are interesting for several reasons. First, epenthesis occurs on target monosyllables with both monomoraic and bimoraic vowels/diphthongs, indicating that this is a general problem with coda consonants that is independent of moraic structure. Second, the coda is generally produced target appropriately, with only eight cases of a change in sonority class in her entire epenthesis corpus. Third, there is extensive variability in the production of a given target, where some words occur with no coda, epenthesized, and with a coda, all on the same day (e.g., *cup* ['kʌː] ~ ['kʌpiː] ~ ['kʌpː]).

Table 14

Naima's number (percent) of target monosyllabic words produced with coda, no coda, or word-final epenthesis

	Coda		***No Coda***		***Epenthesis***	
Age	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
0;11	1/24	(4)	21/24	(88)	2/24	(8)
1;0	1/28	(4)	26/28	(93)	1/28	(4)
1;1	3/21	(14)	14/21	(67)	4/21	(19)
1;2	25/60	(42)	22/60	(37)	13/60	(22)
1;3	259/496	(52)	68/496	(14)	169/496	(34)
1;4	637/792	(80)	39/792	(5)	116/792	(15)
1;5	423/479	(88)	11/479	(2)	45/479	(9)
Total	1349/1900	(71)	201/1900	(11)	350/1900	(18)

Table 15

Naima's number (percent) of target disyllabic words produced with coda, no coda, or word-final epenthesis

	Coda		***No Coda***		***Epenthesis***	
Age	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
0;11	0/0		0/0		0/0	
1;0	1/8	(13)	6/8	(75)	1/8	(13)
1;1	0/2	(0)	2/2	(100)	0/2	(0)
1;2	0/16	(0)	15/16	(94)	1/16	(6)
1;3	21/36	(58)	15/36	(42)	0/36	(0)
1;4	63/87	(72)	23/87	(26)	1/87	(1)
1;5	133/144	(92)	10/144	(7)	1/144	(1)
Total	218/293	(74)	71/293	(24)	4/293	(1)

One might wonder if Naima has more problems producing some target codas than others, thus leading to epenthesis as a production strategy. Further examination of Naima's monosyllabic words finds that epenthesis occurs on all target codas regardless of place or sonority. However, although there was no difference in the rate of epenthesis between fricatives and nasals, there was a higher rate of epenthesis on stops than on both fricatives ($\chi^2 = 11.10$, $df = 1$, $p = .001$) and nasals ($\chi^2 = 8.19$, $df = 1$, $p = .004$), suggesting that she may have more difficulty producing stop codas. These results are shown in Table 16.

Table 16

Naima's number (percent) of epenthesized monosyllabic words as a function of target coda sonority

	Stops		*Fricatives*		*Nasals*	
Age	*Number*	*(%)*	*Number*	*(%)*	*Number*	*(%)*
0;11	1/3	(33)	0/0	--	1/21	(5)
1;0	1/6	(17)	0/10	(0)	0/12	(0)
1;1	2/11	(18)	2/5	(40)	0/5	(0)
1;2	9/40	(23)	4/15	(27)	0/5	(0)
1;3	100/238	(42)	30/129	(23)	39/129	(30)
1;4	83/403	(21)	25/263	(10)	8/126	(6)
1;5	16/270	(6)	21/131	(16)	8/78	(10)
Total	212/971	(22)	82/553	(15)	56/376	(15)

The patterns for disyllables were somewhat different, with 15% of nasals being epenthesized (the same as for monosyllables), but no epenthesis found with stops and fricatives. This may be due in part to the higher coda omission rate in disyllables at the point where epenthesis was taking place.

Of all monosyllabic epenthesized target words, 61% contained word-final stops, 23% contained fricatives, and 16% contained nasals. Thus, although stops constitute the majority of Naima's coda targets, it appears that there may be something particularly challenging about her production of word-final stops. This is further supported by the fact that her aspiration of voiceless stops began at 1;2 along with her production of codas. A comparison of the rates of aspiration and epenthesis on stops is provided in Table 17.

Table 17

Naima's number (percent) of target monosyllabic words ending in a word-final stop that contained final vowel epenthesis or aspiration (when coda produced)

	Stop + Epenthesis		*Stop + Aspiration*	
Age	*Number*	*(%)*	*Number*	*(%)*
0;11	1/3	(33)	0/3	(0)
1;0	1/6	(17)	0/6	(0)
1;1	2/11	(18)	0/11	(0)
1;2	9/40	(23)	18/40	(45)
1;3	100/238	(42)	75/238	(32)
1;4	83/403	(21)	93/403	(24)
1;5	16/270	(6)	4/270	(2)
Total	212/971	(22)	190/971	(20)

The simultaneous appearance of aspiration (on voiceless stops) and epenthesis (mostly on voiced consonants) is potentially relevant given proposals that word-final consonants are actually onsets to empty-headed syllables (CV.C) (e.g., Harris, 1994, Kaye, 1990). Furthermore, it has been proposed that even if this type of syllable structure does not characterize the target language, it may well be true for early stages of acquisition. For example, Goad and Brannen (2003) propose that the delay found in the acquisition of coda consonants by some children, combined with the high prevalence of aspiration or substitution of the target coda with a glottal stop, provides evidence that language learners are treating these consonants as onsets to empty-headed syllables rather that as coda consonants. That is, learners might initially be confused as to the syllabic representation of word-final consonants.

There are several arguments for and against such a proposal in the data examined here. On the supporting side, Naima's use of epenthesis may provide some evidence that target word-final consonants are being prosodified as syllable onsets. The aspirated forms might then be seen as the incomplete realization of the following epenthetic vowel. Further support for this position comes from Naima's variable insertion of epenthetic vowels in word-internal CC sequences (2).

(2) Naima's production of word-internal CC sequences.

	Target Word		*Production*	*Age*
a. Epenthesis				
	duckling	/'dʌklɪŋ/	['gʌkəlɪː]	1;0.28
	broccoli	/'brɑkli/	['mʌkəli]	1;3.26
	sprinkler	/'sprɪŋklɚ/	['fpʌkəlæ]	1;4.3
	backpack	/'bækpæk/	['bɛkəpʌk]	1;4;18
b. No Epenthesis				
	baseball	/'beɪsbɑl/	['beɪsbɑ]	1;4;18
	inside	/in'saɪd/	['ɪnːsaɪd]	1;4;18

Note that all the forms with word-medial epenthesis in (2a) contain /k/ as the first element of the word-medial CC sequence. Except for *backpack*, where the phonotactic boundary is clear, the other examples in (2a) contain a /kl/ sequence, which could either be syllabified as a coda + onset /k.l/ sequence, or with both consonants as a complex onset to the following syllable. This might suggest a "templatic" approach to these word forms (cf. Macken, 1979; Vihman, 1993, 1996; Vihman & Velleman, 2000). Naima's mother also noted that at 1;1.4 years she began to play with the sequence [-ki], suffixing it to several previously well-formed words (e.g., *belly* ['bɛwɛ] → ['bʌki). Recall, however, that Naima's use of these forms is variable. Furthermore, she also occasionally epenthesizes word-initial stop + /l/ clusters (e.g., *glove* [gə'lʌv], *block* [və'lɑk^h] (1;3.12) (see Appendix)), suggesting that epenthesis eases the articulatory transition between stop and /l/. Naima shows no strong patterns of epenthesis with other word-internal clusters (2b), or with other onset clusters (see Kirk & Demuth

(2003) for similar results for Naima from a cluster production study). It thus appears that Naima may have an early preference for CV syllable structures, where stop + /l/ clusters and syllable-final consonants are especially likely to be resyllabified as onsets followed by an epenthetic vowel.

Fikkert (1994) suggests that cases of medial syllable epenthesis found in her Dutch data, like epenthesis on monosyllabic words, provide evidence of a preference for disyllabic feet (e.g., *garage* /χaːˈraːʃə/ [χɑndəˈʀaːjə]). However, Kehoe and Stoel-Gammon (1997) argue that this is not necessarily the case for English, reporting instances of word-medial epenthesis in English where a word-initial disyllabic foot already exists (e.g., *octopus* /ˈɑktəˌpʊs/ [əˈgʌtətəˈpɪs]). Note that this is also true of many of Naima's word-medial cases of epenthesis, where the target word is already a binary foot. It would therefore appear that Naima's motivation for use of epenthesis has more to do with constraints on syllable structure than the creation of binary feet.

Further support for a preferred syllable structure explanation of these findings comes from Naima's occasional shift of stress, either to the resulting second syllable of an epenthesized form, or to the final consonant itself (e.g., *catch* [ˈkiː] ~ [ˈkʌtʰ] ~ [ˈkʌdiː] ~ [kəˈdi]; *cup* [kəˈpi] ~ [kəˈp] (see Appendix)). This again indicates that stops, which result in a rapid decrease in sonority within the rhyme, may present a special challenge for young learners to map into coda position. Rather, there may be a tendency to realize word-final stops as onsets, since stops are the least sonorant and therefore most unmarked choice for onsets cross-linguistically (cf. Pater, 1997).

One might then ask why the other children in this study showed no such epenthesis and aspiration patterns. Ethan did use glottal stops in place of stop codas at an overall rate of 10%, with rates as high as 80% as he produced his first codas at 1;0.23, and 17% at 1;4;0 as his rate of overall coda production reached 89%. This may indicate that segmental accuracy is compromised as syllabic structure becomes more complex. Similarly, we suggest that Naima's extensive use of epenthesis and aspiration is due to her attempts to coordinate her utterances at multiple levels of prosodic structure, prosodifying codas as best she can. Further support for this possibility comes from the fact that the majority (66%) of Naima's epenthesized forms occurred utterance-medially (in (3)). This suggests that Naima, who has a higher MLU than the other children, may be sacrificing syllabic accuracy while attempting larger, more complex multiword productions at a higher level of prosodic structure (e.g., phonological phrases or phonological utterances).

(3) Examples of Naima's epenthesis in utterance-medial contexts.

Target Utterance	*Production*	*Age*
up mommy	[ˈʌbə ˈmɑmi]	1;3.7
clean daddy	[ˈklidə ˈdædi]	1;3.26
big bucket	[ˈbɪgə ˈbʌkɪt]	1;4.18
red lego	[ˈwedə ˈleɪgo]	1;5.5

What of Naima's use of epenthesis to meet word-minimality requirements, or a preference for disyllabic feet? Given the extensive nature of her variability in the realization of target coda consonants between 1;2 and 1;4, it is not clear that epenthesis fills the role of either maintaining word-minimality or preferring disyllabic feet. Rather, Naima's use of epenthesis may best be viewed as a phonotactic constraint, where word-final consonants are prosodified even at the cost of epenthesizing extraneous material.

Could there be other possible explanations for Naima's high rate of epenthesis? For example, Stoel-Gammon and Dunn (1985) suggest that some cases of epenthesis could be "morphological" in nature, functioning as a diminutive affix. The vowel quality on Naima's epenthesized forms varied, with about half being realized as schwa and half as [i] or [ɪ] (e.g., *clown* ['klʌnə] (1;3.12); *rice* ['wʌki] (1;2.23)). However, it is not clear that the forms with an epenthesized high front vowel are necessarily diminutive, since this type of epenthesis also occurs on verbs or adjectives (e.g., *catch* ['kʌːdi] (1;3.12)). Furthermore, we excluded from this study any word where an epenthesized form appeared to have become lexicalized as a disyllabic word. This included 30 instances of the word *cheesy* when Naima was 1;4.10, during which time Naima's mother also began to use this term in reference to *cheese*. Further examination of the mother's speech found no evidence of child-like CVCV (e.g., *horsie*) forms or exaggerated aspirated releases. Though Naima's mother speaks clearly and in a slow tempo, her speech is otherwise very adult-like, providing target CVC words even when the child produces CVCV forms. Thus, Naima's high frequency of CVCV forms for CVC targets appears to be part of her emerging grammar at this time.

Vihman and Vellemen (1989) report similar findings for an English-speaking child Molly about the same age. They suggest that Molly used CVCV "word recipes" as an exploration technique used in her attempt to produce words especially ending in a nasal. Although Naima's productions are much more varied, epenthesis did primarily occur with CVC targets containing a voiced stop (including nasals), suggesting that this may have an articulatory explanation. Naima also shows significant use of "word-play" in her later language development (e.g., 2–3 years), purposely changing sounds and making up her own play language (see also discussion above). Thus, some of Naima's use of epenthesis may constitute the beginning of her creativity with language, as well as with her attempt to accurately produce word-final consonants.

In this section we have shown that one of the participants in this study exhibited the extensive use of epenthesis with target codas between the ages of 1;2 and 1;4. Curiously, this coincided with her onset of coda production, resulting in no coda, coda, and epenthesized forms all being produced at the same point in development. We have argued that the epenthesized forms cannot be analyzed as diminutives, or be due to the effect of the input she hears. Their variable appearance also suggests that they are not word-templates, that word-final consonants are not being treated as onsets to empty-headed syllables, nor that there is a preference for disyllabic feet. Furthermore, the fact that epenthesis should increase along with the increased production of coda consonants in monosyllabic words, and in words with both monomoraic and bimoraic vowels, argues against the necessity of epenthesis to preserve word-minimality. Rather, we suggest that the increase in aspiration, concomitant with the appearance of codas and epenthesis, suggests an articulatory challenge as the child produces longer utterances. This can be thought of as a constraint satisfaction problem, where the child is becoming more faithful to producing the target consonants even at the cost of epenthezising new material (cf. Demuth, 1995; Gnanadesikan, 2004; Pater, 1997; Prince & Smolensky, 1993/2004).

3.4 *Coda production as a function of sonority*

Given Naima's high rate of epenthesis when attempting word-final stops, we might expect sonorant coda consonants to be acquired earlier and more successfully than less sonorant stops. This would be in keeping with general crosslinguistic markedness conditions on syllable structure, where languages that have restrictions on coda consonants typically permit sonorant consonants, maintaining a flatter sonority gradient within the syllable rhyme but a steeper sonority gradient between onset and nucleus (e.g., Clements, 1990, though see Stampe, 1969, for alternative perspectives on markedness). Although frequency and markedness often coincide, with less marked structures typically being higher frequency, the segmental content of English codas is an exception, perhaps due to the early segmental acquisition of stops. This suggests that examining the sonority content of English-speaking children's coda consonants may provide some insight into some of the individual variation in coda production. Stites, Demuth, and Kirk (2004) therefore predicted that language learners might show earlier success in the acquisition of unmarked, more sonorant nasal codas, and later acquisition of the least sonorant stop codas, with fricatives falling somewhere in between. (Liquids were not considered due to their typically late segmental acquisition in English). However, they also noted that language learners are sensitive to frequency effects in the ambient language, showing earlier perceptual preference for higher frequency segments (e.g., Anderson, Morgan, & White, 2003) and earlier production of higher frequency syllable structures and word structures (e.g., Levelt, Schiller, & Levelt, 2000; Roark & Demuth, 2000; Zamuner, Gerken, & Hammond, 2004). Given that stops constitute 43% of all English word-final codas, but fricatives account for only 20% and nasals only 16%, we might expect earlier acquisition of stops in coda position if learners are sensitive to frequency effects in this position (19% are liquids and 1% are affricates). Furthermore, stops are the first consonants to appear in English-speaking children's early productions, whereas liquids are notoriously late (e.g., Smit, 1993).

Kehoe and Stoel-Gammon (2001) show that stops are typically the first coda consonants acquired by most of the children in their study. Furthermore, Stites et al. (2004), found that stops were the first coda consonants acquired by Naima. Thus, some of the aspiration and epenthesis on Naima's target words with stop codas came as she was acquiring her first codas. In contrast, William showed earlier acquisition of the more sonorant nasal and fricative codas, with stops being acquired later. This may help explain William's protracted variability in coda production. These findings point to the fact that some children may be more sensitive to frequency effects whereas others may be more sensitive to markedness in acquiring the phonology of their language. For example, Vihman and Velleman (1989) report that Molly acquired coda nasals before coda fricatives. She also epenthesized nasals, again indicating that epenthesis may be an early strategy used for producing codas.

Extending the results reported in Stites et al. (2004), we find that three of the children in this study showed earlier acquisition of the less sonorant stops, whereas William showed a somewhat different pattern, with earlier production of target fricatives and then nasals. This is shown for each of the children in Table 18.

Table 18

Number (percent) of target monosyllabic coda consonants produced as a function of increasing sonority (stops > fricatives > nasals > liquids)

Naima

	Stops		***Fricatives***		***Nasals***		***Liquids***	
Age	*Numbers*	*(%)*	*Numbers*	*(%)*	*Numbers*	*(%)*	*Numbers*	*(%)*
0;11	0/3	(0)	0/0		1/21	(5)	0/1	(0)
1;0	1/6	(17)	0/10	(0)	0/12	(0)	1/10	(10)
1;1	3/11	(27)	0/5	(0)	0/5	(0)	0/24	(0)
1;2	24/40	(60)	1/15	(7)	0/5	(0)	1/9	(11)
1;3	127/238	(53)	70/129	(54)	62/129	(48)	1/115	(1)
1;4	302/403	(75)	233/263	(89)	102/126	(81)	2/83	(2)
1;5	248/270	(92)	108/131	(82)	67/78	(86)	0/54	(0)
Total	705/971	(73)	412/553	(75)	232/376	(62)	5/296	(2)

Ethan

	Stops		***Fricatives***		***Nasals***		***Liquids***	
Age	*Numbers*	*(%)*	*Numbers*	*(%)*	*Numbers*	*(%)*	*Numbers*	*(%)*
0;11	0/3	(0)	0/1	(0)	0/0		1/4	(25)
1;0	16/37	(43)	9/10	(90)	0/0		1/86	(1)
1;1	27/47	(57)	1/2	(50)	3/25	(12)	0/57	(0)
1;2	81/96	(84)	20/23	(87)	38/54	(70)	0/44	(0)
1;3	90/112	(80)	27/32	(84)	21/35	(60)	0/69	(0)
1;4	249/275	(91)	75/85	(88)	45/60	(75)	1/70	(1)
1;5	58/61	(95)	25/25	(100)	35/37	(95)	5/71	(7)
1;6	200/219	(91)	67/73	(92)	94/95	(99)	23/135	(17)
Total	721/850	(85)	224/251	(89)	236/306	(77)	31/536	(3)

Lily

	Stops		Fricatives		Nasals		Liquids	
Age	*Numbers*	*(%)*	*Numbers*	*(%)*	*Numbers*	*(%)*	*Numbers*	*(%)*
1;1	2/7	(29)	1/2	(50)	1/2	(50)	0/4	(0)
1;2	0/0		1/1	(100)	0/0		1/5	(20)
1;5	0/0		1/1	(100)	0/3	(0)	0/3	(0)
1;6	4/5	(80)	6/6	(100)	3/18	(17)	0/2	(0)
1;7	57/59	(97)	9/11	(82)	5/19	(26)	0/16	(0)
1;8	163/173	(94)	66/67	(99)	41/45	(91)	1/19	(5)
1;9	103/107	(96)	59/61	(97)	56/60	(93)	3/26	(12)
Total	329/351	(94)	143/149	(96)	106/147	(72)	5/77	(7)

William

	Stops		Fricatives		Nasals		Liquids	
Age	*Numbers*	*(%)*	*Numbers*	*(%)*	*Numbers*	*(%)*	*Numbers*	*(%)*
1;4	43/84	(51)	7/9	(78)	9/15	(60)	2/22	(9)
1;6	27/63	(43)	34/36	(94)	17/22	(77)	0/12	(0)
1;7	78/95	(82)	25/30	(83)	55/65	(85)	3/37	(8)
1;8	120/147	(82)	31/35	(89)	84/113	(74)	2/55	(4)
1;9	65/82	(79)	24/25	(96)	55/64	(86)	2/31	(7)
1;10	84/92	(91)	51/52	(98)	59/69	(86)	2/38	(5)
1;11	43/54	(80)	14/16	(88)	26/30	(87)	7/22	(32)
2;0	83/119	(70)	49/56	(88)	34/41	(83)	13/45	(29)
2;1	110/128	(86)	24/27	(89)	58/66	(88)	2/70	(3)
Total	653/864	(76)	259/286	(91)	397/485	(82)	33/332	(10)

Naima acquires the least sonorant coda consonants first, counter to proposals that acquisition patterns should proceed unmarked to marked. Rather, she first masters the highest frequency codas (stops), and then proceeds to the others. Ethan and Lily show early acquisition of stops and fricatives, with somewhat later acquisition of nasals. Their patterns of acquisition are therefore similar to the sonority sequence found with Naima, but with less of a distinction in timing of acquisition between fricatives and stops. William is more variable than the other children, with fricatives and then nasals showing higher rates of production earlier than the high-frequency stops.

Thus, for most of the children in this study stops are the earliest and most accurately produced of all coda consonants. This indicates that English language learners are sensitive to statistical properties of the input, mapping higher-frequency segments into their prosodic structures earlier than lower frequency segments, despite the fact that these may be cross-linguistically more marked. These findings are consistent with the general pattern found by Kehoe and Stoel-Gammon (2001), where (voiceless) stops were the first coda consonants to appear. We found no tendency in this study for the more sonorant nasals to be acquired first, neither as part of a bimoraic nucleus, nor as part of an unmarked syllable (cf. Fikkert, 1994). Despite the fact that nasal codas might be easier to prosodify and produce than stops, the children in this study tended to produce stops and fricatives first. Naima seems particularly determined in this regard, with her productions resulting in epenthesis, aspiration, and the occasional shift in stress.

4 Discussion

This paper has investigated four children's longitudinal acquisition of early monosyllabic prosodic words with word-final consonants between the ages of one and two. It found relatively rapid acquisition of coda consonants overall, and earlier acquisition of coda consonants in target words with short vowels, consistent with other cross-sectional studies of English (Kehoe & Stoel-Gammon, 2001). This suggests that codas are first acquired in contexts where they are prosodically licensed as one of the moras of the syllable rhyme. It also suggests that these children are aware of subsyllabic structure much earlier than has been generally thought. For example, Demuth and Fee (1995) suggested that at the stage of development where children produced subminimal CV words, they might not be aware of the moraic level of prosodic structure, but only the level of the syllable and above. However, in this study we see that children are producing subminimal, monomoraic CV forms at the same time that they are also producing well-formed bimoraic CVC words. Thus, it appears that segmental and phonotactic constraints, rather than a lack of access to prosodic structure, play a more important role in explaining the production of early subminimal words. It also suggests that moraic adjustment of vowels might be more typical of older children like Gwendolyn, who produced her first coda consonant around 2;6 (Bernhardt & Stemberger, 1998, p. 416). Perhaps by this age English-speakers are more aware of language-specific constraints on the structure of prosodic words. Naima did exhibit vowel lengthening (CV:) when some codas were omitted, but since this occurred with both monomoraic and bimoraic vowels it is not clear that this was a process of moraic adjustment. This is obviously an area for future acoustic research.

The notion of prosodic licensing is an interesting one that has been found elsewhere in the acquisition of phonology, especially at the interface between prosodic structure and morphology. For example, Lleó and Demuth (1999) report that determiners appear earlier in the speech of Spanish as opposed to German children. They argue that this is due to the fact that the higher frequency of three-syllable words with medial stress in Spanish (e.g., *muñeca* 'doll') provides Spanish-speaking children with earlier access to higher levels of prosodic structure than their English-learning counterparts. This then also facilitates the early prosodic licensing of determiners, even at the cost of omitting a syllable from the lexical word (e.g., *la muñeca* [a'meka] 'the doll' (Demuth, 2001; Lleó, 2001)). In contrast, German determiners are fully-stressed lexical items rather than prosodic clitics. This means that German-speaking children must advance to the two-word stage of development before determiners begin to appear.

Recent results from three of the children in this study (Naima, Ethan, and William) also show that 3rd person singular -*s* appears more frequently in verbs that have no coda consonant than in those that already have a coda consonant (e.g., *see* → *sees* vs. *tap* → *taps*) (Song, 2004). Although it may be that syllable structure complexity, rather than moraic structure per se, is the relevant factor here, these findings suggest that aspects of prosodic structure may also play a role in licensing grammatical morphemes at the level of the syllable.

Of course, higher-level prosodic factors such as stress and word-final lengthening, have also been shown to affect the production of segments (Echols, 1992; Echols & Newport, 1992). Kirk and Demuth (2006) suggest that the increased duration of monosyllables, stressed syllables, and word-final position all contribute to more accurate coda production in English-speaking two-year-olds in novel word-production tasks. Lleó (2003) and Prieto and Bosch-Baliarda (in press) show similarly that the production of coda consonants in Spanish and Catalan respectively is also affected by stress. Thus, coda consonants are more likely in children's disyllabic word productions if they occur in a stressed syllable. What is different about the prosodic licensing of codas found in the present study is that these occurred in monosyllabic words, where higher-level aspects of prosody were held constant. Thus, prosodic licensing of segments and morphemes appears to take place at different levels of prosodic structure, both within the domain of the syllable, and as part of the larger prosodic word.

The other factor of interest in this study was the child Naima's pervasive use of epenthesis to prosodify her coda consonants. Her use of epenthesis was not categorical, showing extensive variability on the same word on the same day. It would appear that this child has a tendency to prefer CV syllable structures, breaking up CC sequences in various contexts (as complex onsets, word-medially, and between words), and preferring to prosodify codas as onsets if she could. However, the fact that she can and does produce codas at the same time indicates a concurrent ability to handle more complex syllable structures. This shows that her structural representations are intact, and that this is not a general low-level articulatory problem (e.g., MacNeilage, 1980). It also shows that her productions are not templatic, all taking the same form. Importantly, this child's use of epenthesis does not appear to be used to preserve word-minimality, nor is it used to create disyllabic feet. Rather, she appears to sacrifice syllable complexity for increased complexity at the higher level of the phonological phrase or utterance, stringing together many more words per utterance than her peers. Thus, for some children, simplification of syllable structure may be traded for greater complexity at higher levels of prosodic structure.

Stampe (1969) notes that obstruents tend to be become voiceless across languages due to the effect of oral constriction impeding the airflow required for voicing. It is also the case that adult-like voicing contrasts are acquired late, and children's early productions of stops are often perceived by adults as being voiceless (e.g., Macken & Barton, 1980; Scobbie, Gibbon, Hardcastle, & Fletcher, 2000). This is not a problem for a child learning German, but Stampe points out that English-speaking children have to suppress this tendency. Furthermore, American English stops often tend to be unreleased, relying on contrastive vowel length to indicate coda voicing distinctions (Hussain & Nair, 1995). Perhaps Naima uses epenthesis and aspiration as a means of maintaining voicing distinctions between voiced and voiceless word-final consonants. That is, perhaps she uses these mechanisms as a means of overriding natural articulatory processes to approximate target segments before she can use vowel length as a reliable cue to voicing. Future research involving acoustic analysis would be needed to evaluate this possibility. Other children, such as William, might solve this problem by tending to avoid the production of stop codas. Lily's selection of early CVCV targets might be another mechanism for avoiding word-final consonants. Like Fikkert (1994), then, we suggest that English word-final coda consonants may be hard to produce, but we have shown here that epenthesis is used to ensure production of coda consonants, and not as a preference for disyllabic feet. The situation may be different for Dutch, a language that requires syllables be to bimoraic. It could be that Dutch learners conserve moraic structure by employing epenthesis until bimoraic syllables can be produced.

Although various biological, motor and cognitive theories have been proposed for explaining aspects of children's early productions (e.g., Ferguson & Farewell, 1975; Locke, 1983; McNeilage, 1980; Vihman, Ferguson, & Elbert, 1986), results from the current study suggest that coda consonants present articulatory challenges for the very young language learner, both phonotactically and with respect to preserving voicing contrasts. Some learners delete coda consonants, epenthesize, or aspirate. Others avoid codas altogether by focusing on other types of target words. Despite these types of individual variation, however, these children have much in common, producing their first coda consonants in contexts where these are licensed as part of a binary foot. We propose that these findings can best be understood in terms of constraint satisfaction problem. Coda consonants at the ends of words present language learners with a special challenge, but children must also learn to produce other levels of prosodic structure as well. One problem for language learners, then, is determining what level of prosodic structure to begin with. Some children may initially focus on entire utterances, producing intonational contours with no identifiable segments or words. Many, however, focus initially at the level of prosodic words or feet, gradually moving down the hierarchy to encode moraic structure, and up the hierarchy to produce larger phonological phrases and utterances. Thus, learners may show individual difference in their point of entry into the prosodic system of a language, and this may give rise to early variability in the shape of their early words and utterances.

5 Conclusion

The purpose of this paper was to evaluate previous claims that children learning English may be aware of word-minimality effects. Four children's spontaneous word productions were examined from the onset of first words until monosyllabic target words with word-final codas were produced with at least 80% coda accuracy. Children's early prosodic words were then examined regarding coda consonant production as a function of vowel type (monomoraic vs. bimoraic), epenthetic processes, and segmental effects of sonority. Accuracy on vowel production in monosyllables was high, suggesting that there was no systematic attempt to produce bimoraic words when coda consonants were omitted from monosyllables with monomoraic vowels. However, the participants were more accurate at producing coda consonants in monosyllables with monomoraic rather than bimoraic vowels. This confirms Kehoe and Stoel-Gammon's (2001) finding that children tend to produce coda consonants earlier in contexts where these are prosodically licensed as part of a bimoraic foot. This points to the possibility that young language learners may be aware of moraic structure, even if they do not exhibit moraic adjustment processes when coda consonants are not produced. Finally, this study determined that the high levels of word-final epenthesis found in the productions of one child were most likely due to constraints on the production of complex syllable structure, or an attempt to preserve coda consonant voicing contrasts, rather than an effort to preserve word-minimality or produce binary feet. Further research examining the interface between developing syllable and word structure, and in languages where the mora plays different roles at the level of the syllable and the word, may shed further light on children's developing awareness of lower levels of prosodic structure, and how language-specific constraints on prosodic structure are learned.

References

ANDERSON, J., MORGAN, J., & WHITE, K. (2003). A statistical basis for speech sound discrimination. *Language and Speech*, **46**, 155–182.

BERNHARDT, B., & STEMBERGER, J. (1998). *Handbook of phonological development*. San Diego: Academic Press.

BROSELOW, E. (1995). Skeletal positions and moras. In J. Goldsmith (Ed.), *The handbook of phonological theory* (pp. 175–205). Cambridge, MA: Blackwell.

CATTS, H. W., & JENSEN, P. J. (1983). Speech timing of phonologically disordered children: Voicing contrast of initial and final stop consonants. *Journal of Speech Hearing Research*, **26**, 501–510.

CLEMENTS. G. N. (1990). The role of the sonority cycle in core syllabification. In J. Kingston & M. Beckman, (Eds.), *Papers in laboratory phonology I* (pp. 283–333). Cambridge: Cambridge University Press.

DELATTRE, P. (1965). *Comparing the phonetic features of English, French, German, and Spanish*. Heidelberg: Julies Gross Verlag.

DEMUTH, K. (1995). Markedness and the development of prosodic structure. In J. Beckman (Ed.), *Proceedings of the North East Linguistic Society*, **25**, (pp. 13–25). Amherst, MA: GLSA, University of Massachusetts.

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: Lawrence Erlbaum Associates.

DEMUTH, K. (2001). Prosodic constraints on morphological development. In J. Weissenborn & B. Höhle (Eds.), *Approaches to bootstrapping: Phonological, syntactic and neurophysiological aspects of early language acquisition*, (pp. 3–21). Amsterdam: John Benjamins. *Language acquisition and language disorders series 24.*

DEMUTH, K., & FEE, E. J. (1995). *Minimal prosodic words in early phonological development*. Ms., Brown University and Dalhousie University.

DEMUTH, K., & JOHNSON, M. (2003). Truncation to subminimal words in early French. *Canadian Journal of Linguistics*, **48**, 211–241.

DOKE, C. M., & MOFOKENG, S. M. (1985). *Textbook of Southern Sotho grammar*. Cape Town: Longman.

ECHOLS, C. (1992). A perceptually-based model of children's earliest productions. *Cognition*, **46**, 245–296.

ECHOLS, C., & NEWPORT, E. (1992). The role of stress and position in determining first words. *Language Acquisition*, **2**, 189–220.

FEE, E. J. (1995). Segments and syllables in early language acquisition. In J. Archibald (Ed.), *Phonological acquisition and phonological theory* (pp. 43–61). Hillsdale, NJ: Lawrence Erlbaum Associates.

FEE, E. J. (1996). Syllable structure and minimal words. In B. Bernhardt, J. Gilbert, Z. & D. Ingram, (Eds.), *Proceedings of the UBC international conference on phonological acquisition* (pp. 85–98). Somerville, MA: Cascadilla Press.

FEE, E. J., & INGRAM, D. (1982). Reduplication as a strategy of phonological development. *Journal of Child Language*, **9**, 41–54.

FERGUSON, C. A., & FAREWELL, C. (1975). Words and sounds in early language acquisition: English initial consonants in the first fifty words. *Language*, **51**, 419–430.

FIKKERT, P. (1994). *On the acquisition of prosodic structure*. Doctoral dissertation, University of Leiden, The Netherlands.

GNANADESIKAN, A. (2004). Markedness and faithfulness constraints in child phonology. In R. Kager, J. Pater & W. Zonneveld (Eds.), *Constraints in phonological acquisition* (pp. 73–109). Cambridge, U.K.: Cambridge University Press.

GOAD, H., & BRANNEN, K. (2003). Phonetic evidence for phonological structure in syllabification. In J. van de Weijer, V. J. van Heuven & H. van der Hulst (Eds.), *The phonological spectrum*, vol. **2** (pp. 3–30.). Amsterdam: John Benjamins.

GOAD, H., & BUCKLEY, M. (2005). *Prosodic structure in Child French: Evidence for the Foot.* Ms., McGill University.

GRIJZENHOUT, J., & JOPPEN, S. (1998). First steps in the acquisition of german phonology: A case study. Theory des Lexikons; Arbeiten Sonderforschungsbereichs 282, Nr. 110.

HAMMOND, M. (1999). *The phonological of English: A prosodic optimality-theoretic approach.* Oxford, U.K.: Oxford University Press.

HUSSAIN, S., & NAIR, R. (1995). Voicing and aspiration contrasts in Hindi and Urdu. *Papers from the 31st Meeting of the Chicago Linguistics Society*, University of Chicago, Chicago.

HARRIS, J. (1994). *English sound structure.* Oxford, Blackwell.

HYMAN, L. (1985). *A theory of phonological weight*. Cinnamonson, NJ: Foris.

KAYE, J. (1990). "Coda" licensing. *Phonology*, **7**, 301–330.

KEHOE, M., & STOEL-GAMMON, C. (1997). The acquisition of prosodic structure: An investigation of current accounts of children's prosodic development. *Language*, **73**, 113–144.

KEHOE, M., & STOEL-GAMMON, C. (2001). Development of syllable structure in English-speaking children with particular reference to rhymes. *Journal of Child Language*, **28**, 393–432.

KIRK, C., & DEMUTH, K. (2003). Onset/coda asymmetries in the acquisition of clusters. In B. Beachley, A. Brown, & F. Conlin (Eds.), *Proceedings of the 27th Annual Boston University Conference on Language Development* (pp. 437–448). Somerville, MA: Cascadilla Press.

KIRK, C., & DEMUTH, K. (2006). Accounting for variability in 2-year-olds' production of coda consonants. *Language Learning and Development*, **2**, 97–118. <http://www.cog.brown.edu/people/demuth/articles/2005kirk&demuthLLD%2705.pdf>

LADEFOGED, P. (1993). *A course in phonetics*. Third edition. New York: Harcourt Brace Javanovich.

LEVELT, C. C., SCHILLER, N. O., & LEVELT, W. J. (2000). The acquisition of syllable types. *Language Acquisition*, **8**, 237–264.

LLEÓ, C. (1997). Filler syllables, proto-articles and early prosodic constraints in Spanish and German. In A. Sorace, C. Heycock & R. Shillcock (Eds.), *Language acquisition: Knowledge, representation and processing. Proceedings of GALA '97*, 251–256.

LLEÓ, C. (1998). Proto-articles in the acquisition of Spanish: Interface between phonology and morphology. In R. Fabri, A. Ortmann & T. Parodi (Eds.), *Modele der Flexion: 18. Jahrestagung Der Deutschen Gesellschaft für Sprachwissenschaft*. Tübingen: Niemeyer Verlag.

LLEÓ, C. (2001). The Interface of phonology and morphology: The emergence of the article in the early acquisition of Spanish and German. In J. Weissenborn & B. Höhle (Eds.), *Approaches to bootstrapping: Phonological, syntactic and neurophysiological aspects of early language acquisition*, (pp. 23–44). *Language acquisition and language disorders Series 24.* Amsterdam: John Benjamins.

LLEÓ, C. (2003). Prosodic licensing of codas. *Probus*, **15**: 257–281

LLEÓ, C., & DEMUTH, K. (1999). Prosodic constraints on the emergence of grammatical morphemes: Crosslinguistic evidence from Germanic and Romance languages. In A. Greenhill, H. Littlefield, & C. Tano (Eds.), *Proceedings of the 23rd Annual Boston University Conference on Language Development* (pp. 407–418). Somerville, MA: Cascadilla Press.

LOCKE, J. L. (1983). *Phonological acquisition and change.* New York: Academic Press.

MACKEN, M. A. (1979). Developmental reorganization of phonology: A hierarchy of basic units of acquisition. *Lingua*, **49**, 11–49.

MACKEN, M. A., & BARTON, D. (1980) The acquisition of the voicing contrast in English: A study of voice onset time in word-initial stop consonants. *Journal of Child Language*, **7**, 41–74.

MacNEILAGE, P. F. (1980). The control of speech production. In G. Yeni-Komshian, J. Kaveanagh, & C. Ferguson (Eds.), *Child phonology vol. 1*: *Production*, (pp. 9–21). New York: Academic Press.

MacWHINNEY, B. (2000). *The CHILDES Project: Tools for analyzing talk. Third edition.* Vol. **2**: *The database.* Mahwah, NJ: Lawrence Erlbaum Associates.

MATTHEI, E. H. (1989). Crossling boundaries: More evidence for phonological constraints on early multiword utterances. *Journal of Child Language*, **16**, 41–54.

OTA, M. (1999). *Phonological theory and the acquisition of prosodic structure: Evidence from child Japanese*. Doctoral dissertation, University of Georgetown.

PATER, J. (1997). Minimal violation and phonological development. *Language Acquisition*, **6**, 201–253.

PRIETO, P., & BOSCH-BALIARDA, M. (in press). The development of codas in Catalan. *Catalan Journal of Linguistics*, **5**.

PRINCE, A., & SMOLENSKY, P. (1993/2004). *Optimality theory: Constraint interaction in generative grammar*. Cambridge, MA: Blackwell Pulbishers.

ROARK, B., & DEMUTH, K. (2000). Prosodic constraints and the learner's environment: A corpus study. In S. Catherine Howell, Sarah A. Fish, & Thea Keith-Lucas (Eds.), *Proceedings of the 24th Annual Boston University Conference on Language Development*, (pp. 597–608). Somerville, MA: Cascadilla Press.

SALIDIS, J., & JOHNSON, J. S. (1997). The production of minimal words: A longitudinal case study of phonological development. *Language Acquisition*, **6**, 1–36.

SCHWARTZ, R., LEONARD, L. B., WILCOX, J. J., & FOLGER, J. K. (1980). Again and again: Reduplication in child phonology. *Journal of Child Language*, **7**, 75–88.

SCOBBIE, J. M., GIBBON, F., HARDCASTLE, W. J., & FLETCHER, P. (2000). Covert contrast as a stage in the acquisition of phonetics and phonology. In M. B. Broe & J. B. Pierrehumbert

(Eds.), *Papers in laboratory phonology V: Acquisition and the lexicon*. Cambridge: Cambridge University Press. 194–207.

SMIT, A. (1993). Phonologic error distributions in Iowa-Nebraska Articulation Norms Project: Word-initial consonant clusters. *Journal of Speech and Hearing Research*, **36**, 931–947.

SMIT, A. B., & BERNTHAL, J. E. (1983). Voicing contrasts and their phonological implications in the speech of articulation-disordered children. *Journal of Speech and Hearing Research*, **26**, 486–500.

SONG, J. Y. (2004). *Effects of syllable structure complexity on the early production of word-final grammatical morphemes.* Ms, Brown University.

STAMPE, D. (1969) The acquisition of phonemic representation. *Papers from CLS 5*, 433–444. Chicago: CLS.

STEMBERGER, J. P. (1992). A performance constraint on compensatory lengthening in child phonology. *Language and Speech*, **24**, 207–218.

STOEL-GAMMON, C., & BUDER, E. (1999). Vowel length, postvocalic voicing and VOT in the speech of two-year olds. *Proceedings of the XIIIth International Conference of Phonetic Sciences*, **3**, 2485–2488.

STOEL-GAMMON, C., & DUNN, C. (1985). *Normal and disordered phonology in children*. Austin, TX: PRO-ED.

STITES, J., DEMUTH, K., & KIRK, C. (2004). Markedness versus frequency effects in coda acquisition. In A. Brugos, L. Micciulla, & C. E. Smith (Eds.), *Proceedings of the 28th Annual Boston University Conference on Language Development (*pp. 565–576). Somerville, MA: Cascadilla Press.

VELTEN, H. (1943). The growth of phonemic and lexical patterns in infant speech. *Language*, **19**, 281–292.

VIHMAN, M. M. (1993). Variable paths to early word production. *Journal of Phonetics*, **21**, 61–82.

VIHMAN, M. M. (1996). *Phonological development: The origins of language in the child*. Oxford: Blackwell.

VIHMAN, M., FERGUSON, C. A., & ELBERT, M. (1986). Phonological development from babbling to speech: Common tendencies and individual differences. *Applied Psycholinguistics*, **7**, 3–40.

VIHMAN, M. M., & McCUNE, L. (1994). When is a word a word? *Journal of Child Language*, **21**, 517–542.

VIHMAN, M. M., & VELLEMAN, S. (1989). Phonological reorganization: A case study. *Language and Speech*, **32**, 149–170.

VIHMAN, M. M., & VELLEMAN, S. L. (2000). The construction of a first phonology, *Phonetica*, **57**, 255–266.

WEISMER, G. (1984). Acoustic analysis strategies for the refinement of phonological analysis. In: Elbert, M., Dinnsen, D. A. & Weismer, G. (Eds.), *Phonological theory and the misarticulating child. ASHA Monographs*, Vol. **22**. Rockville, MD: ASHA, 30–52.

WEISMER, G., DINNSEN, D. A., & ELBERT, M. A. (1981). A study of the voicing distinction associated with omitted, word-final stops. *Journal of Speech and Hearing Disorders*, **46**, 320–327.

ZAMUNER, T., GERKEN, L. A., & HAMMOND, M. (2004). Phonotactic probabilities in young children's speech production. *Journal of Child Language*, **31**, 515–536.

Appendix

Naima's variable production (types) of target codas in monosyllabic words at 1;3.12

Target Word		*Output Pronunciation*		
		No Coda	*Epenthesis*	*Coda*
clap	/ˈklæp/			[ˈklʌf]
cup	/ˈkʌp/	[ˈkʌː]	[ˈkopi], [kəˈpi], [ˈkʌpiː], [ˈkʌblɛ]	[ˈkʌːp],[ˈkʌpʰ], [ˈkʌp], [kəˈp], [ˈkʌfp], [ˈkʌf]
lap	/ˈlæp/			[uəˈlæp]
soap	/ˈsop/			[ˈsoːpʰ]
boat	/ˈbot/			[ˈbʊtʰ], [ˈbuːtʰ]
cat	/ˈkæt/			[ˈkʌtʰ]
caught	/ˈkɑt/			[ˈkʌtʰ]
eat	/ˈit/			[ˈit]
tweet	/ˈtwit/	[ˈdi]		
wheat	/ˈwit/	[ˈwi]		
seed	/ˈsid/		[ˈsidə], [ˈsiːdə]	[ˈsɪd]
slide	/ˈslaɪd/		[ˈtlædə], [ˈslædaɪ]	
bawk	/ˈbʌk/	[ˈbʌ]	[ˈbʊkɛ], [ˈbʌkiː]	[ˈbʌkə], [ˈbɑkə], [ˈbʌk], [ˈbʌkʰ]
block	/ˈblɑk/			[vəˈlɑkʰ]
chick	/ˈtʃɪk/			[ˈtʃɪkʰ]
clock	/ˈklɑk/			[ˈklɑkʰ]
duck	/ˈdʌk/			[ˈdʌkʰ]
quack	/ˈkwæk/	[ˈgæ]		
stick	/ˈstɪk/			[ˈstɪkʰ]
stuck	/ˈstʌk/			[ˈstɪkʰ]
yolk	/ˈjok/		[ˈjʌgi], [ˈjoku]	[ˈjokʰ], [ˈjukʰ]
big	/ˈbɪg/	[ˈbi]	[ˈbigə], [ˈbiːgə]	[ˈbikʰ]
egg	/ˈɛg/		[ˈigə]	[ˈɪːkʰ]
frog	/ˈfrɑg/		[ˈfæːgæ]	
pig	/ˈpɪg/		[ˈpiːgə]	
rag	/ˈræg/	[ˈwʌə]	[ˈwægə]	

off	/'ɑf/			['æf], ['ɑf], ['ɛf],
glove	/'glʌv/		['gluvɑ], ['glʌvə]	[gə'lʌv]
juice	/'dʒus/			['dus], ['dʊs]
kiss	/'kɪs/			['kis], ['kɪs]
mice	/'maɪs/			['mʌs]
rice	/'raɪs/			['wæːs], ['ræs], ['wʌks], ['wʌkʰ]
slice	/'slaɪs/			['bʌʔɪs]
shoes	/'ʃuz/	['di]	['ʃuʒi], ['tuzi], ['ʃuzi], ['ʒuzi], ['ʃuzis]	
noise	/'nɔɪz/	['gui], ['nui]		
nose	/'noz/		['nozɪ]	
beach	/'bitʃ/	['biː]		['biːtʰ], ['bits]
catch	/'kætʃ/	['kiː]	['kʌːdi], [kə'di], ['kʌdi], ['kʌdiː], [k'di]	['kʌtʰ]
vroom	/'vrum/		['bumæ]	
clean	/'klin/		['klinə]	
clown	/'klaʊn/		['klʌnə], ['klʌːdə], ['kʰlʌnə], ['klɑːnə], ['klɛnə]	[kə'lʌn]
down	/'daʊn/	['dɛo], ['do], ['daʊ], ['taʊ]	['dunə]	
fan	/'fæn/	['finə]	['finə], ['fijə], ['ɑnə]	
Joan	/'dʒon/			['nũn], ['dun]
on	/'ɑn/			['ɑn]
train	/'tʃreɪn/			['tiːn]
ring	/'rɪŋ/	['wiː]	['wɪŋə]	['wɪŋ]