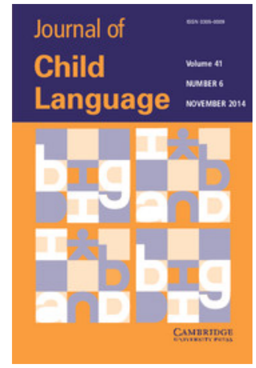

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Development of syllable structure in English-speaking children with particular reference to rhymes*

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ABSTRACT

This study investigates acquisition of the rhyme using cross-sectional and longitudinal data from 14 English-speaking children (aged 1;3–2;0). It focuses on 4 questions pertaining to rhyme development, which are motivated from current theories of prosodic acquisition: 1. Do children make vowel length errors in early acquisition?; 2. Do children acquire coda consonants before they learn the vowel length contrast?; 3. What consonants are first acquired as codas?; and 4. Is there a size constraint such that children's productions are minimally and maximally bimoraic? The results indicate that the percentage of vowel length errors across all children was low irrespective of the percentage of codas produced. In particular, two children produced very few coda consonants and made few vowel length errors, suggesting that mastery of vowel length was not secondary to coda acquisition. With respect to coda segments, children produced voiceless obstruents as codas before sonorants supporting generally the claim that obstruents emerge before sonorants in coda position. Children produced coda consonants more frequently after short than long vowels consistent with a bimoraic size constraint in syllable development. The paper concludes by comparing the English findings with cross-linguistic work on vowel length acquisition.

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INTRODUCTION

Current theories of phonological acquisition draw strongly on the rich representational frameworks of modern phonological theory. In particular, the focus on prosodic structure and constituency in the adult domain has received a parallel focus in recent accounts of early prosodic development. Using theories of syllable structure as a basis, we examine an area of syllable structure development which remains relatively unexplored in English, namely, the rhyme. We investigate children's acquisition of simple versus complex nuclei, children's acquisition of codas and the relationship between the two in early phonological development. In so doing, we evaluate two models of prosodic acquisition which make predictions regarding rhyme development: Fikkert's (1994) parametric theory of syllable structure in Dutch and Demuth & Fee's (1995) theory of children's early word shapes based on the notion of the minimal word (i.e. a bimoraic size constraint in acquisition). Both of these models make claims regarding the rate of development of different aspects of the rhyme and the size of the rhyme in early acquisition. Our study comprises cross-sectional and longitudinal data from 14 English-speaking children (aged 1;3–2;0). We first provide an overview of terminology and basic principles in prosodic theory insofar as they are relevant to later discussion. Following this theoretical background, we describe Fikkert's (1994) and Demuth & Fee's (1995) models and then review the literature on the acquisition of syllable structure in English.

Terminology

A review of the literature on syllable structure necessitates some discussion of terminology, particularly with reference to the terms 'vowel length' and 'tense' versus 'lax.' In many languages of the world, some vowels are characterized by longer durations than other vowels. In this study, we are interested in length differences that can be attributed to the prosodic (or phonetic) notion of quantity and not to extrinsic factors such as word and phrasal stress, position within the phrase, and consonantal context. If we examine sets of supposed long and short vowels in identical conditions across languages, we observe that languages differ as to whether the distinction is one of quantity or of both quantity and quality. By quality, we refer to vowel formant differences resulting from different vocal tract configurations; by quantity, to length differences. In languages such as Norwegian, Finnish, and Czech, pairs of long and short vowels have the same vocal tract configuration and differ only in duration, whereas in languages such as German, Dutch, and English, long and short vowel pairs may involve quality distinctions as well (Nooteboom, 1972). In the latter group of languages, the distinction between tense and lax is relevant. Tense/lax, as an articulatory label, is controversial as it refers to different things in different languages (Clark & Yallop, 1995). Vowels described as tense and lax may differ according to pharyngeal width, tongue tension, tongue position, and length. In simple terms, tense vowels involve a greater degree of deviation from uniform vocal tract configuration and involve more accurate approximation to their intended target than lax vowels (Anderson, 1984).

In discussions of the tense/lax opposition in English, there is a long-standing debate as to whether quantity or quality is more central in explaining the distinction (Giegerich, 1992; Harris, 1994). Studies of phonetic length show that the difference between lax and tense vowels is relatively unmarked in English with a lax-to-tense ratio of 0·71 (House, 1961) and extrinsic factors, such as the voicing of the following consonant, may obscure absolute length measurements. Perceptual tests also show that quality not quantity may play the greater role in vowel identification. For example, if a speaker utters the word *beat* with the vowel quality of /i/ but with the vowel length of /ɪ/, a listener will still interpret this word as *beat* not *bit* (Giegerich, 1992). This finding, as well as the fact that in some dialects of English (e.g. Scottish) the length difference between tense and lax vowels is neutralized (Giegerich, 1992), suggest that quantity is secondary to quality in the distinction of tense and lax vowels.

Despite the primary role of quality in English vowel identification, most phonological descriptions of English vowels still maintain the distinction between long and short vowels, where long refers to tense vowels and diphthongs and short to lax vowels. The different behavior of the two classes of vowels with respect to stress and phonotactic rules suggests that a phonological quantity distinction is relevant. This can be captured in structural terms through the nonlinear treatment of syllable structure to which we now turn.

Basic principles of prosodic theory

Recent work in prosodic theory recognizes a hierarchical arrangement of prosodic units at and below the word level referred to as the prosodic hierarchy (Selkirk, 1984; Nespor & Vogel, 1986; McCarthy & Prince, 1986, 1993). These units include the mora (μ), the syllable (σ), the foot (F), and the prosodic word (PrWd). Each level in the hierarchy is comprised of units from the level directly below. The lowest level is characterized by the mora, a subsyllabic constituent which determines syllable weight. Light syllables contain one mora and heavy syllables contain two moras. Languages differ, however, in which segments count as moraic; in Latin and English, coda consonants as well as vowels count as moraic, whereas in St Lawrence Island Yupik, only vowels count as moraic (Hayes, 1995).

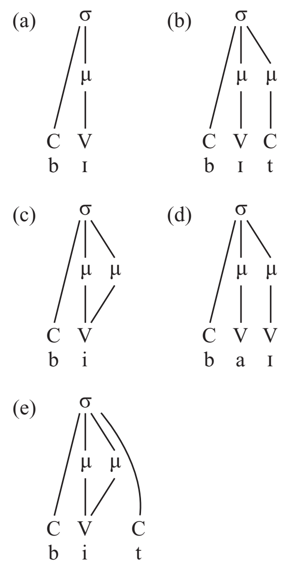

Fig. 1. Moraic representation of syllable types in English.

Figure 1 shows the moraic representation of different syllable types in English: (1a) is the monomoraic form [bɪ] consisting only of a lax vowel; (1b) is the bimoraic form [bɪt] *bit*, consisting of a lax vowel and consonant; (1c) is the bimoraic form [bi] *bee* consisting of a tense vowel; (1d) is the bimoraic form [baɪ] *buy* consisting of a diphthong; and (1e) is the bimoraic form [bit] *beat* consisting of a tense vowel plus consonant. Under the assumption that rhymes are maximally bimoraic (Kager & Zonneveld, 1986), the coda consonant in *beat* is extrarhymal and does not contribute to syllable weight. Thus, the /t/ is shown attaching to the syllable node and not to the mora. In addition, prevocalic segments directly link to the syllable node and do not contribute to syllable weight. The moraic representation illustrated in Fig. 1 captures the phonological regularity that syllables containing either a short vowel plus consonant, a long vowel, or a diphthong contain equivalent syllable weight, that is, two moras. In English, these syllables are heavy for the purposes of stress assignment and can occur in word-final position under accent. A monomoraic syllable such as [bɪ] in (1a) is not a possible word form in English.

Zec (1995), working within a moraic framework, distinguishes sonority constraints that pertain to the syllable (the only mora of a light syllable or the leftmost mora of a heavy syllable) and to the mora (all moraic positions). The set of syllabic segments forms a subset of the set of moraic segments. According to Zec's typology, English is a language, in which all segments may contribute to syllable weight. The syllabicity constraint determines that the leftmost mora must include sonorant segments (vowels and sonorant consonants); the moraic constraint is left unspecified, allowing vowels, sonorants, or obstruents to occupy the rightmost mora. Thus, in English, an obstruent consonant can be moraic as shown above in (1b). In contrast, other languages may be more restrictive in terms of sonority constraints. As mentioned, some languages allow only vowels as moraic segments, other languages permit only sonorant and not obstruent consonants to be moraic, for example, Lithuanian.

An alternative way of representing syllable structure is via onset-rhyme constituency (McCarthy, 1979; Selkirk, 1982). The onset dominates all prevocalic elements and the rhyme, all other elements. The rhyme is further divided into the nucleus and the coda. Figure 2 shows the representation of

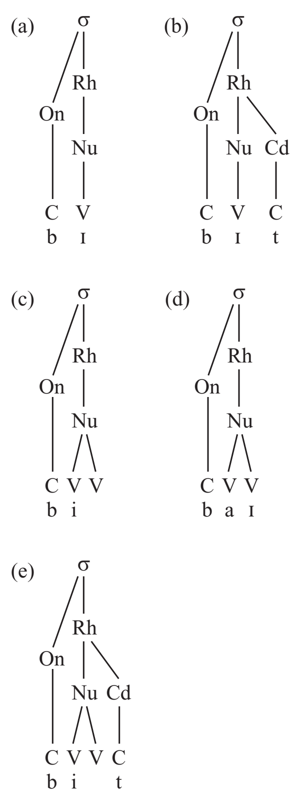

Fig. 2. Onset-rhyme representation of syllable types in English.

different English syllable types in onset-rhyme theory. Heavy syllables are distinguished from light syllables according to whether they have a branching nucleus or rhyme: syllables containing long vowels, such as (2c) *bee* and syllables containing diphthongs, such as (2d) *buy* have branching nuclei; syllables with coda consonants, such as (2b) *bit* have branching rhymes. There exists some controversy regarding the primitive status of the constituents 'onset' and 'rhyme' and for this reason, many linguists use these terms as descriptive devices only. The aim of this study is not to evaluate these two theories of syllable structure. We mainly adhere to a moraic theory of syllable structure but like others, use the terms 'onset' and 'rhyme' for descriptive convenience.

Syllables are grouped into feet, the principal unit of stress representation. A general condition on foot form (Foot Binarity) determines that feet must be binary at some level of analysis (McCarthy & Prince, 1986, 1993). Thus, a foot can contain two syllables or one bimoraic syllable. Finally, feet are organized into prosodic words. The smallest prosodic word is referred to as the minimal word and is derived from the prosodic hierarchy taken together with the foot binarity condition. Because the prosodic word must contain a foot, and because a foot must be either bimoraic or bisyllabic then a prosodic word must contain at least two moras or two syllables. The concept of the minimal word is relevant in explaining a variety of linguistic phenomena. The formation of nicknames, hypocoristics, and reduplicative morphological processes across languages attest to the importance of a bimoraic size restriction (McCarthy & Prince, 1993).

Returning to English vowel classification, the preceding discussion has indicated that there is a phonological vowel length distinction which relies on the opposition between tense and lax. Diphthongs, being composed of two vowel elements, pattern together with tense vowels as members of the long vowel set. The association between tense/lax and phonological length may appear paradoxical in English, since we have already noted that quality rather than quantity plays the primary role in the tense/lax distinction. A solution to this paradox is suggested by Anderson (1984), who, taking into consideration articulatory as well as length differences between tense and lax vowels, argues that tense vowels are internally more complex than lax vowels and this complexity can be translated into complexity within the syllable nucleus in terms of the number of moraic units. In essence, structural accounts of nucleus complexity need not only refer to phonetic length.

It should also be noted that phonological length is not purely a phonetic property in several world languages. For example, in Dutch, many phonotactic regularities point to a systematic opposition between long and short vowels, yet phonological length only partly corresponds to phonetic duration. Phonologically short vowels are phonetically short but phonologically long vowels may be phonetically long or short. The mid and low vowels /a/, /e/,

/o/, and /ø/ are phonetically long, while the high vowels /i/, /y/, and /u/ are phonetically short except when directly preceding /r/ (Kager, 1989; Booij, 1995). In addition, quality (vowel height) differences also exist between the mid long vowels /e, o/ and their short phonological counterparts /ɛ, ɔ/.

In this study, we are interested in children's acquisition of the phonological vowel length distinction[1] or in other words, the distinction between simple (monomoraic or non-branching) and complex nuclei (bimoraic or branching). This, in turn, depends upon children's acquisition of tense versus lax vowels as well as diphthongs. Throughout the paper, we will use the terms 'long' and 'short' synonymously with the terms 'tense' and 'lax' to refer to vowels which differ in quantity. The reader must keep in mind, we are referring to the abstract notion of quantity and not to phonetic length *per se*. Similarly when we refer to vowel length errors, we are referring to substitutions between the categories: long (tense vowels and diphthongs) and short (lax vowels) and not to errors of phonetic length.

Developmental models of syllable structure

Two main models relating to rhyme acquisition have emerged from recent studies of early speech development: Fikkert's (1994) parametric theory of syllable structure and Demuth & Fee's (1995) theory of children's early word shapes based on the notion of the minimal word. Both models make predictions regarding the rate of development of different aspects of the rhyme and the size of the syllable in early acquisition.

On the basis of the vowel length to weight relationship in Dutch (the length contrast exists only in closed syllables in Dutch), Fikkert hypothesized that children acquire final consonants before they learn differences in vowel length. This prediction was borne out in her longitudinal study of 12 Dutch-speaking children. She observed that children produced closed syllables before they mastered vowel length. However, the matter was slightly more complicated than this, in that final obstruents appeared before sonorants and these two classes of consonants differed in terms of the relationship they had with the preceding vowel. She proposed specific syllable parameters to account for four stages in children's rhyme development.

At stage 1, children have set no syllable parameters. They produce core syllables consisting of a consonant and vowel. Although both long and short vowels are produced at this stage, they are used randomly and inter-

[1] We use the term 'distinction' or 'contrast' to refer to a phonemic distinction, that is, a linguistic feature which is unpredictable and must be lexically defined. Due to the controversy regarding the tense-lax contrast in English, it is unclear what is lexically listed. Some argue it is the quantity distinction expressed in X-slots (or moras) which is lexically listed (Anderson, 1984); others argue it is the feature [+/−tense] which is later translated to X-slots or moras through default rules (Giegerich, 1992).

changeably, suggesting that vowel length is not contrastive and that all vowels are still represented with a non-branching nucleus. At stage 2, children set the branching rhyme parameter allowing the rhyme to branch into a nucleus and coda. Fikkert noted that children produce obstruents before sonorants in syllable-final position. At stage 3, children set the branching nucleus parameter allowing the representation of long and short vowels. Fikkert observed that children acquire vowel length representation initially before sonorants. The evidence for this was that children shortened target long vowels before sonorants and lengthened target short vowels when deleting sonorants; no length relationship was found with obstruents. Finally, at stage 4, children set the extrarhymal parameter, allowing a bipositional rhyme to accommodate an additional consonant. It is at this stage that children acquire vowel length representation before obstruents. Fikkert's (1994) stages of syllable parameters are summarized in (1).

(1) Syllable parameters (Fikkert, 1994)

a.
Branching rhyme parameter:
Rhymes can branch into a nucleus and a coda
[No/ Yes]

b.
Branching nucleus parameter:
The nucleus can be branching [No/ Yes]

c.
Extrarhymal parameter:
A (final) bipositional rhyme can be followed by an extra consonant.
[No/ Yes]

Demuth & Fee's (1995) model shares many similarities with that of Fikkert's, largely because it incorporates Fikkert's data; however, it also links together developmental findings in Dutch and in English. Like Fikkert, Demuth & Fee (1995) propose that children's first prosodic forms are core syllables, in which neither coda consonants nor vowel length contrasts are systematically employed. Central to Demuth & Fee's approach is the next stage of development, the minimal word stage, in which children's productions are minimally and maximally bimoraic. They distinguish three separate sub-stages within this developmental period. Before children have acquired subsyllabic structure, the minimal word is satisfied by a bisyllabic CVCV form. The tendency of children to reduplicate monosyllables or epenthesize syllables is suggestive of this stage of development (Demuth & Fee, 1995; Fee, 1996), although Demuth & Fee note that not all children pass through this sub-stage. The second sub-stage is when children acquire coda consonants, and the third is when children acquire vowel length contrasts.

Once children are able to reliably produce a long vowel and coda consonant, they have progressed beyond the minimal word stage. A summary of Demuth & Fee's (1995) early stages of prosodic development is shown in (2). We utilize the same symbols employed by Demuth & Fee; however, given that children cannot control vowel length prior to Stage 2c, CV actually refers to CV(V) at stage 1; (C)VCV refers to (C)V(V)CV(V) at stage 2a; and (C)VC refers to (C)V(V)C forms at stage 2b, where the vowel enclosed in parenthesis indicates that the vowel may be long or short (Salidis & Johnson, 1997).

(2) Stages of prosodic development (Demuth & Fee, 1995)

Stage 1.

Core Syllable CV

Stage 2.

Minimal Words

a. Core syllables (C)VCV	(μμ)
b. Closed syllables (C)VC	(μμ)
c. Vowel length distinctions (C)VV	(μμ)

Regarding sub-syllabic development, Demuth & Fee (1995) do not provide justification for why codas are acquired before vowel length contrast. Their claims appear to stem from Fikkert's finding in Dutch and some preliminary data in English. Regarding a size constraint in acquisition, they provide a stronger rationale. The minimal word is the unmarked prosodic form, which has a special status cross-linguistically. This stage may provide a constrained learning space during which children learn language-specific syllable structure while at the same time producing well-formed prosodic words. Because the minimal word forms an upper bound on prosodic form, Demuth & Fee predict trading effects between different prosodic shapes. They observed that when children acquire vowel length distinctions, they may show alternations between closed syllables containing a lax vowel and open syllables containing tense vowels. For example, one child in their study, MH, displayed variable productions of the word *egg* (e.g. [ɛg], [ɪʔ], [ʔe]) all of which satisfied the minimal word constraint (Demuth & Fee, 1995, p22).

Although the minimal word constraint is not central to Fikkert's account, she also recognizes a developmental stage in which children's productions in terms of syllable structure are minimally and maximally bipositional. This is stage 3 in which children are more likely to delete a final sonorant after a long vowel, or retain a final sonorant after a short vowel; they show no such systematic pattern with obstruents, producing obstruents most of the time after long and short vowels. Fikkert surmises that vowels before obstruents are monopositional, thus, allowing syllables with obstruent codas to also conform to a bipositional rhyme template.

Recently, Salidis & Johnson (1997) evaluated Fikkert's (1994) and Demuth & Fee's (1995) models using data from a detailed study of Kyle, aged 0;10–1;8. They found lukewarm support for Demuth & Fee's model and very little for Fikkert's. They observed that there was a period up until 1;4–1;5 in which Kyle reduced complex targets to minimal words. After this time, forms greater than bimoraic were frequently produced for complex or 'supra-minimal' targets. They noted, however, that a monosyllabic production constraint could just as easily have explained their child's early prosodic strategy since bisyllabic minimal forms were scarce. Kyle made few vowel errors from the beginning of data collection providing little support for a lack of vowel length representation in early acquisition. He produced coda consonants early as well (55% accuracy at 11 months), counter to the notion of a core syllable stage. The authors did not identify any particular class of consonants that were produced early as codas: At 1;2, Kyle most often produced final /p, b, t, k, s, m/ and deleted /g, z, n, l, θ/, providing little support for a simple coda parameter which allows obstruents before sonorants.

Overall, Salidis & Johnson's (1997) results are inconsistent with the specific predictions of both Demuth & Fee's (1995) and Fikkert's (1994) models, although the existence of a prosodically defined stage of acquisition (i.e. minimal word) was, to some degree, attested. Nevertheless, their study focused on a single subject and further analysis of a larger subject pool is warranted to determine whether their findings are sufficiently generalizeable. This is the purpose of the current study. Before describing it, however, we review other findings on children's rhyme development in English. Studies on vowel and consonant acquisition, although conducted outside the framework of modern prosodic theory, provide useful information on children's development of vowel length and coda consonants.

Vowel length and coda consonant development

Studies on vowel acquisition in English clearly reveal that certain vowels are mastered before others (Davis & MacNeilage, 1990; Pollock & Keiser, 1990; Stoel-Gammon & Herrington, 1990; Otomo & Stoel-Gammon, 1992). The corner vowels /i, ɑ, u/ plus the mid back tense vowel /o/ and central /ʌ/ are acquired relatively early and the front vowels /e, ɛ, ɪ/ and the rhotic vowels /ɝ, ɚ/ are acquired relatively late. Vowels such as /œ, ʊ, ɔ, ə/ tend to be in the middle in terms of order of acquisition (see Stoel-Gammon & Herrington, 1990). What has been less clear from vowel acquisition studies is the importance of the contrast between long (tense vowels and diphthongs) and short (lax vowels) in accounting for children's error patterns. It is not simply the case that children acquire tense before lax vowels because certain tense vowels (e.g. /e/) emerge late and the lax vowel /ʌ/ is purportedly mastered early. The late acquisition of some lax vowels, however, has led researchers to consider phonetic factors such as vowel duration as possible influences in vowel development. For example, Otomo & Stoel-Gammon (1992) suggest that the shortness of the vowels /ɪ, ɛ/ may hinder children's ability to achieve the correct articulatory target. Yet, even in their study, the most frequent substitution patterns with these vowels were lowering of lax /ɪ/ to lax [ɛ] and lax /ɛ/ to lax [æ]. Only in the younger age group did children show a tendency to substitute the tense vowel [i] for lax /ɪ/. Furthermore, the later acquisition, in general, of lax over tense vowels is not necessarily an indication of the lack of an underlying vowel length distinction. If children have not acquired a branching nucleus, one might expect an intermixing of tense and lax vowels, wherein target /i/ would be produced as [ɪ] and [i] and target /ɪ/ produced as [i] and [ɪ]. The random use of long and short vowels as an error pattern was reported by Fikkert with Dutch children but does not seem to have been frequently reported in English. Other aspects of phonological vowel length development such as diphthong acquisition have not been well researched, although Pollock & Keiser (1990) report quantity-type errors with diphthongs in a group of phonologically disordered children; that is, children frequently substituted monophthongs for diphthongs.

Demuth & Fee (1995) argue that PJ (aged 1;8) does not use vowel length contrastively because he uses both long and short vowels interchangeably for a given target. However, based on the examples cited, Demuth & Fee (1995) appear to be imposing upon their data a vowel length contrast which is not phonemic in English. The distinction between phonemically/phonologically long and phonetically long (PJ produces [du] & [duː] for target *juice* & [bo] & [boː] for target *ball*) is not one that applies in adult English and judging these forms as examples of unsystematic vowel length control is questionable. An adult, on one occasion uttering the word *shoe* as [ʃu] (Where's my shoe?) and on a later occasion, perhaps with greater emotional force, uttering the word *shoe* as [ʃuː] (There's my *shoe*!), would not be judged as having unsystematic vowel length control. In fact, out of 14 productions, only on one occasion does PJ make a tense-lax substitution, producing [dʊs] for *juice*.

Several studies have examined acquisition of word-final consonants in English (Fey & Gandour, 1982; Stoel-Gammon, 1985), although many questions pertaining to codas remain unanswered. For example, Bernhardt & Stemberger (1998) note that few studies have examined whether codas are permitted from the earliest stages of phonology. Stemberger's child Morgan (aged 0;11) had codas even in her first word *up* ([ʔɑp]) and on no occasion deleted a word-final coda. Bernhardt & Stoel-Gammon (1996) report that 35% of a group of normally developing children regularly produced at least two of their first 10 words with coda consonants. The general viewpoint since Jakobson (1968/1941) is that codas are not produced in early acquisition, consistent with Fikkert's (1994) and Demuth & Fee's (1995) claim that children's earliest forms are core syllables.

Stoel-Gammon's (1985) longitudinal study of children's phonetic inventories provides information on which consonants develop first in coda position. Voiceless stops and the nasal [n] predominated in most of her subject's inventories with [t] the first coda consonant in the speech of more than half of the (34) children. Likewise, Bernhardt & Stemberger (1998) conclude that the order of coda acquisition is typically voiceless stops and nasals followed by fricatives and voiced stops. On the basis of these studies, the pattern in English is not consistent with Fikkert's observations that obstruents as a class emerge before sonorants.

Trading effects between different prosodic shapes suggestive of a minimal word constraint have been reported by Bernhardt & Stemberger (1998). For example, Morgan (aged 1;2) produced long vowels and diphthongs in open syllables but only short vowels in closed syllables. It was noted that closed syllables containing diphthongs may be particularly problematic for children. Stemberger's Gwendolyn disallowed diphthongs in closed syllables until 2;6.

Recently Harris, Watson & Bates (1999) present a case study of an English-speaking child, aged 4;11–6;7, with a vowel length disorder which respects the minimal size of the phonological word. His production of target long vowels displayed three patterns of deviance: 1. Shortening, by which long vowels were produced as short (*weed* was produced as [wɪd]); 2. Bisyllabification, by which target words containing VVr were produced as two syllables (*tire* was produced as [tɔjə]); and 3. Hardening, by which long vowels or diphthongs were rendered with a short vowel plus oral stop (*cow* was produced as [kɑb]; *he* was produced as [hɪʒ]). The authors account for these seemingly unrelated patterns by arguing that their subject has not yet learnt the marked branching setting necessary for the representation of the vowel length contrast. The child is only able to realize a non-branching or monomoraic nucleus but, nevertheless, maintains bimoraic minimality by producing two syllables or by reassigning the right-hand position of the branching nucleus to a non-nuclear position such as the coda. Additional support for the preservation of bimoraicity comes from the observation that vowel shortening only occurred in target closed syllables. That is, shortening was blocked if it presented a threat to the minimal size of the phonological word.

In sum, this survey of the literature on vowel acquisition and coda consonant development in English provides conflicting evidence for several aspects of Demuth & Fee's (1995) and Fikkert's (1994) models, in particular for the claim regarding the late acquisition of the vowel length contrast. Salidis & Johnson's (1997) results suggest that vowel length is acquired relatively early in English, whereas Harris *et al.*'s (1999) case study of a phonologically disordered child is consistent with the order of acquisition proposed by Fikkert (1994) and Demuth & Fee (1995). It is clear more systematic examination of this topic is warranted, because most vowel studies have not focused on the length distinction *per se* nor on the relationship between vowel length and coda consonant development.

Purpose of study

The purpose of the current study is to examine children's acquisition of the rhyme, that is, children's acquisition of simple versus complex nuclei, children's acquisition of codas, and the relationship between the two in phonological development. By investigating this topic, we address claims made by Fikkert (1994) and Demuth & Fee (1995) regarding the rate of development of different aspects of the rhyme and the size of the syllable in early acquisition. The main questions we pose are:

1. Do children make vowel length errors in early acquisition?
2. Do children acquire coda consonants before they learn the vowel length contrast?
3. What consonants are acquired early in coda position? In particular, do obstruents emerge before sonorants?
4. Is there is a size constraint in early development such that children's productions are minimally and maximally bimoraic?

The first question seeks to establish the frequency of vowel length errors in early acquisition. Because the phonological length distinction is based both on the acquisition of tense versus lax vowels as well as on diphthongs, we count the number of errors within these categories. Following Fikkert(1994), Demuth & Fee (1995), and Salidis & Johnson (1997), we rely on transcriptional data but make reference to phonetic length measures later in the discussion. Two separate analyses are employed to investigate vowel length. First, we examine the percentage of times target words occur with vowel length alternations. That is, restricting ourselves to those target words which contain multiple repetitions, how many times amongst this group are there forms with vowel length alternations (e.g. the target word *bead* is produced with tense and lax variants, [bid] and [bɪd]). As argued by Salidis & Johnson (1997), assessing vowel length variation within target forms may be preferable to counting the number of vowel length errors across targets forms, since consistent production of the wrong vowel (i.e. no vowel length alternations) may be more suggestive of vowel substitution errors rather than a lack of vowel length control. Nevertheless, to remain consistent with Fikkert's (1994) analysis procedure, we examine in our second analysis, the percentage of forms produced with a long vowel substituted for a short vowel or a short vowel substituted for a long vowel.

The second question concerns the rate of development of different aspects of the rhyme (nucleus vs. coda). To address this question, we compare two measures: the percentage of coda consonants produced and the percentage of productions produced with target vowel length. Given Fikkert (1994) and Demuth & Fee's (1995) theories, we predict that children should still make vowel length errors while they are in the process of acquiring codas. Several different scenarios are possible in terms of coda and vowel length development. If children's coda production is low, the percentage of forms with the correct target vowel length should also be low, because children are at the beginning of rhyme development when they have not acquired codas or the vowel length contrast. If children's coda production is high, there are two possibilities. One is that the percentage of forms with the correct vowel length is low, because they are just beginning to acquire vowel length, and the other is that the percentage of forms with the correct vowel length is high, because they are at the latter stage of rhyme development when they have acquired both coda and vowel length control. One scenario should not be possible: coda production is low and vowel length accuracy is high. According to Fikkert (1994) and Demuth & Fee (1995), if children are not producing coda consonants, they are at the core syllable stage, when vowel length is not acquired. At this stage, children employ long and short vowels interchangeably. One issue, of course, is in deciding what criteria should be used to determine vowel length acquisition. Fikkert (1994) considers Jarmo's percentage of vowel length errors (38% at stage 2) indicative of random vowel length control. In this study, we adopt the criterion of 30% errors as being suggestive of significant vowel length errors.

To investigate the third question, we examine the consonant inventories of children at different stages of coda production. This analysis should provide information on which classes of consonants emerge first in coda position.

Finally, we investigate the notion of a size constraint in two different ways. First, we examine the percentage of codas produced after long and short vowels. Given the assumption that short vowels are represented as monomoraic and long vowels as bimoraic, a consonant is needed after a short vowel to satisfy the bimoraic constraint but not after a long vowel as the constraint is already satisfied. Thus, we predict greater percentages of consonants after short versus long vowels. Second, we examine the percentages of children's productions which are sub-minimal (monomoraic), minimal (bimoraic), and supra-minimal (greater than bimoraic) for the supra-minimal target form (C)VVC. If there is a constraint on syllable size, children should produce the majority of (C)VVC words as minimal forms.

METHOD

Database

The data come from a series of studies at the University of Washington, in which children of various ages were encouraged to produce monosyllabic and disyllabic target words. The main purpose of these studies was to examine children's acquisition of intrinsic and extrinsic vowel length control (see Stoel-Gammon & Buder, 1998), but the same data can be usefully employed to test theories of early syllable structure development. Here, we refer to two different data sets: The first data set consists of cross-sectional information on 10 children (5 children aged 1;6 and 5 children aged 2;0; 6 females and 4 males); and the second data set consists of longitudinal information on four children (2 females and 2 males) tested at 1;3, 1;6, 1;9, and 2;0. No data are analysed for one child at age 1;3 because he produced no recognizable words.[2] We employ cross-sectional and longitudinal data-sets because both provide relevant information on children's syllable structure development; the cross-sectional by providing a perspective on typologies of syllable structure, and the longitudinal by providing direct developmental information. At the time of testing, all children were within a one week interval of their designated age and received scores exceeding the 20th percentile for their age on the vocabulary section of the MacArthur Communicative Developmental Inventory: Toddlers (Fenson, Dale, Reznick, Thal, Bates, Hartung, Pethick & Reilly, 1991).

The data for all children were collected in a similar way. Children were tested in two 30-minute sessions separated by a one-week interval. In the cross-sectional data set, this meant that each child's corpus was based on two separate test sessions and in the longitudinal data set, information at each age interval was based on two test sessions. In each session, children participated in games and elicitation tasks in which they were encouraged by an experimenter and parent to produce multiple tokens of stimulus words. Both the child and the experimenter wore a vest containing a microphone attached to a FM transmitter. The audio signal sent to the FM receiver was recorded onto the audio channel of a videotape simultaneously with a video signal. Following testing, all productions of stimulus words were phonetically transcribed by a single observer (the first author). A list of productions for each child in the cross-sectional study and for each age-level in the longitudinal study was then compiled. Productions which were inaudible, masked by noise, or uttered with exaggeration were excluded. Productions were also coded as to whether they were spontaneous or imitated (followed

[2] The same child, L4, produced only one glossable word at 1;6 *ball* which he rendered with several different phonetic forms [bɔ], [bɔbɔ], [buː], [bubu].

an adult production within two utterances). Imitated utterances constituted 22% of the total number of utterances and subsequent analyses indicated no effect of imitation on vowel length or coda consonant accuracy; hence, imitated and spontaneous productions were pooled together.

Examples of the stimulus words appear in Appendix A. For the purpose of the original study, monosyllabic words were selected to include contrasts between open versus closed syllables (*bee* vs *beet*), tense versus lax vowels (*beet* vs *kit*), and final consonants varying in voice and manner (*beet*, *bead*, *bees*, *bean*). Fluffy toys were given specific names (e.g. 'Dude'[dud], 'Biz'[bɪz], 'Pete'[pit], 'Kit'[kɪt], etc.,) to augment contrasts not available from common English children's words. Children's truncations of disyllabic targets with syllable-final stress were also included, for example, [bun] for *ba****lloon***; [wæf] for *gi****raffe***. Children were encouraged to produce some or all of the designated target words (i.e. words listed in Appendix A) but any word spontaneously produced during a test session could be included in the final data-set. Disyllabic words produced by the children are also listed in Appendix A. Our focus is on children's monosyllabic productions but disyllabic productions will be considered in the analysis of prosodic size constraints.

To avoid the likelihood that the token count was biased by multiple productions of certain words, no more than five productions of each rhyme type for a given target word was included in the database. Rhyme type refers to the content of the rhyme only. For example, the forms [se] and [ne] for *snake* were coded as the same type because the rhymes were identical, although the onsets varied; the forms [seʔ] and [sek] were coded as different types because they had different codas. In the classification of rhyme structure, however, the latter forms were coded as identical because they both contained a tense vowel plus coda.

The total number of monosyllabic tokens included in the transcribed database was 4158. A subset of words (n = 1013 or 24% of the data) was re-transcribed by a second observer who had experience in phonetic transcription. The subset included the productions of four children: two of whom made frequent use of codas and two of whom made infrequent use of coda consonants. Reliability between transcribers was determined for the following five measures: vowel accuracy (agreement in terms of the vowel used), vowel-length (agreement in terms of the categories: long (tense vowels and diphthongs) and short (lax vowels)), coda marking (agreement in terms of whether a coda was present or not), coda accuracy (agreement in terms of the coda consonant used), and coda manner (agreement in terms of the manner of articulation of the coda consonant). In the latter measure, glottal stops were counted as stop consonants. Reliability for all five measures was good: vowel accuracy (88%), vowel length (95%), coda marking (93%), coda accuracy (82%) and coda manner (90%). Most disagreement for vowel length category stemmed from confusions among the vowel pairs [ɑ]/[æ], [ɑ]/[ʌ] and [i]/[ɪ].

Data coding

The rhyme structure of each child's productions was determined from the phonetic transcription. Consonants, including glottal stops, were represented as C, tense vowels and diphthongs as VV, and lax vowels as V. In the coding of vowel length errors, the following vowel classification system, based on Ladefoged (1993), was employed: the vowels /i, e, ɑ, o, ɔ, u/ were considered tense and /ɪ, ɛ, æ, ʌ, ɝ, ʊ/ were considered lax. Phonetic length was transcribed but was not taken into consideration in vowel length coding. Thus the forms [bi] and [biː] for target *bead* were both coded as tense/long. Phonetically long lax vowels (e.g. [bɪː] for *bib*) were relatively infrequent in the transcription (17 examples in the entire database). They were still counted as short. Vowel errors in which a lax vowel was substituted for another lax vowel, a tense vowel was substituted for another tense vowel, or a tense vowel was substituted for a diphthong and vice-versa were not counted as length errors. One controversial decision was with the vowel /ɔ/ which in American English is often classified as lax. Because the subjects came from the west coast of the United States (Seattle area), where the /ɑ/ versus /ɔ/ distinction tends to be neutralized, productions of this vowel were generally uncommon. When it did occur, it was coded as long. Some classification systems propose that because low vowels (e.g. /æ/) are phonetically long, they should also be classified as tense. We maintain the classification of /æ/ as a lax vowel because phonologically it patterns like other lax vowels.

Data analysis

Vowel-length contrast. Our analyses of vowel length errors are presented in two ways. First, we indicate the percentage of times target words occur with vowel length variation. Only those target words which contain multiple repetitions are included in the analysis. Second, we indicate the percentage of times children make vowel length errors (across all productions), separating the data according to whether the error is one of shortening (a tense vowel or diphthong is produced as a lax vowel) or lengthening (a lax vowel is produced as a tense vowel or diphthong). These analyses are presented respectively as Analyses 1 and 2 in Table 1.[3] Examples of vowel length errors

[3] Only those target forms in which tense/lax alternations constitute at least 20% of the variable forms are included in Analysis 1. For example, L2-2;0 produced 8 exemplars of *biz* /bɪz/: 4 productions as [bɪz]; two productions as [bɛz]; one production as [bɛʔ]; and one production as [biz]. Because the child maintained the correct vowel length contrast most of the time (7/8 times), these productions are not included in this analysis.

from selected children are listed in Table 2. When target forms are produced with the correct as well as the incorrect target vowel length, both examples are provided in the table. Children are listed in order of discussion in the text. Subject identity is as follows: L1-1;3(F) refers to a female subject (aged 1;3) in the longitudinal database; C1-1;6(F) refers to a female subject (aged 1;6) in the cross-sectional database.

Analysis 1 shows that most children (13/14) exhibited several instances of vowel length variation, although the percentage of target forms with variable productions was low. In general, alternations between the high vowels /i/ and /ɪ/, /u/ and /ʊ/, and between the low vowels /æ/ and /ɑ/ and the central vowel /ʌ/ were relatively common; alternations between the mid tense/lax cognates /e/ and /ɛ/ and quantity changes involving diphthongs were less common.[4] Potential instances of vowel length difficulty came from children at the earliest stages of word production, in particular, L1 and L2 at 1;3 and C1-1;6 and C4-1;6 in the cross-sectional study. L1-1;3 produced 5 out of 9 targets with vowel length variation (thus, yielding 55 % targets with variable forms); L2-1;3 produced 4/10, C1-1;6 produced 3/11, and C4-1;6 produced 6/27. In addition, L3 at 1;3 made several vowel errors although his three targets with multiple repetitions did not contain vowel length variation. These results must be considered tentative, however, because of the small numbers of target forms with multiple repetitions produced by the children in these sessions.

Additional useful information comes from Analysis 2 which includes all productions and which separates vowel errors according to substitution patterns. In this analysis, we observe that several children showed a tendency to either substitute short for long vowels (e.g. C4-1;6, L4-1;9) or long for short vowels (e.g. C5-1;6, C8-2;0). For example, Table 2 shows that Subject C4-1;6 frequently produced tense vowels /i, e, ɑ, o/ and the diphthongs /aʊ, aɪ/ with lax vowel substitutes. He produced *keys* as [kɪt], *snake* as [sɛk], [sɪk],or [sʌk], *box* as [bɛts], *boat* as [bʊt], and *house* as [hæs]. He produced target lax vowels generally accurately suggesting his patterns may be more indicative of a consistent lax for tense substitution than a lack of vowel length representation. Subject L4-1;9 displayed a similar pattern in that certain tense vowels were produced as lax, although in most cases the lax vowel was either [ɪ] or [ʌ] (e.g. *tail* [tɪʔ], *shoe* [ʃɪ], [ʃɪʔ], *cow* [kʌ]). Subject L4's patterns may reflect a preference for earlier babbling patterns, since [ɪ] and [ʌ] were common vowels in his babbled utterances. However, he did not produce only

[4] Salidis & Johnson (1997) examined vowel length alternations for the tense and lax forms /i, ɪ, e, ɛ, u, ʊ/ only, thus, avoiding the likelihood of over-interpreting some vowel substitutions as length errors. In any case, if the smaller set of tense/lax cognates were analyzed only, the percentages of forms with vowel length variation would be lower than currently indicated.

TABLE 1. *Results of vowel-length error analyses*

Child	Analysis 1		Analysis 2	
	No. of targets[a]	Percentage var. forms	VV → V[b] (%)	V → VV (%)
L1-1;3(F)[c d]	**9**	**55**	**19 (5/26)[e]**	**21 (6/28)**
L2-1;3(F)	**10**	**40**	**25 (9/36)**	**29 (4/14)**
L3-1;3(M)	**3**	**0**	**67 (4/6)**	**0 (0/6)**
L4-1;3(M)	No glossable words			
L1-1;6	35	9	10 (10/102)	31 (21/67)
L2-1;6	40	3	4 (6/134)	19 (16/85)
L3-1;6	27	4	5 (5/105)	2 (1/43)
L4-1;6	1	0	0 (0/8)	0
C1-1;6(F)	**11**	**27**	**18 (6/33)**	**0 (0/9)**
C2-1;6(F)	22	9	5 (3/60)	13 (4/31)
C3-1;6(F)	26	0	2 (2/92)	6 (2/31)
C4-1;6(M)	**27**	**26**	**38 (30/79)**	**2 (1/57)**
C5-1;6(M)	**27**	**19**	**6 (5/89)**	**31 (12/39)**
L1-1;9	69	1	2 (5/221)	5 (7/148)
L2-1;9	48	0	1 (1/156)	3 (3/100)
L3-1;9	13	8	0 (0/26)	7 (2/27)
L4-1;9	**34**	**21**	**36 (39/107)**	**10 (7/70)**
L1-2;0	50	4	1 (1/136)	9 (9/101)
L2-2;0	79	3	1 (2/250)	3 (4/153)
L3-2;0	54	6	1 (2/165)	6 (6/107)
L4-2;0	40	10	13 (16/127)	2 (1/63)
C6-2;0(F)	50	14	6 (10/157)	19 (14/75)
C7-2;0(F)	46	11	4 (5/127)	16 (10/63)
C8-2;0(F)	**65**	**14**	**3 (7/218)**	**43 (30/69)**
C9-2;0(M)	26	15	3 (3/88)	17 (6/36)
C10-2;0(M)	40	10	13 (18/140)	0 (0/48)

[a] Number of targets refers to lexical items with multiple repetitions.
[b] V, short/lax vowel; VV, long/tense vowel or diphthong.
[c] Data of children marked in bold are presented in Table 2.
[d] L1-1;3(F) refers to a female subject (age 1;3) in the longitudinal database. C refers to the cross-sectional database.
[e] Raw scores are listed in parentheses.

these vowels. Target lax vowels /æ/ and /ʊ/ were produced correctly (e.g. *cat* [tæʔ]; *hat* [hæʔ]; *book* [bʊʔ]; *put* [pʊ]), thus indicating that L4 did not reduce all vowel categories to the same set of vowels. Again, the tense/lax alternations seem to be more suggestive of vowel substitution errors, particularly the use of [ɪ] and [ʌ], than with a lack of vowel length contrast. Subjects C5-1;6 and C8-2;0 (also L1-1;6) displayed the opposite pattern; they produced more than 30% of their lax vowels as tense, but produced

TABLE 2. *Examples of vowel length variation for selected children*

Child	Cat[a]	Vowel	Word/Child production
L1-1;3	VV	/ɑ/	*doll* [daʊ], [dɑ], [dʌ]
		/ɔ/	*ball* [bɑ], [bʌʔ], [bʌ]
		/aɪ/	*eye* [ɑɪ], [æʔ], [æ]
	V	/ɪ/	*kick* [kæ], [kʌ], [ke]
		/ʌ/	*up* [ʌp], [op], *duck* [dʌʔ], [dɑ]
L2-1;3	VV	/ɑ/	*dog* [dɑt], [dʌk], [dʌʔ], *pop* [pʌʔ], [pʌp]
		/o/	*go* [go], [gʌ]
	V	/ʊ/	*book* [bʌk], [bɑk]
		/ʌ/	*duck* [dʌk], [dɑk]
L3-1;3	VV	/ɔ/	*ball* [bæ]
		/u/	*shoe* [ʃɪ]
		/aʊ/	*mouth* [mæː]
C1-1;6	VV	/i/	'*di*' [gi], [gʌ]
		/ɑ/	*sock* [sʌk], [kwʌʔ]
		/ɔ/	*ball* [bɔ], [bʌʔ]
		/u/	*shoe* [ʃu], [ʃʌ]
C4-1;6	VV	/i/	*beet* [bɛt], *teeth* [tip], [tɪf]
			keys [his], [kɪt]
		/e/	*face* [f^{w}ɛs], *snake* [sɛk], [sɪk], [sʌk]
		/ɑ/	*box* [bɑʃ], [bɛts], [bæʃ], *clock* [kæt]
			frog [hʌ]
		/o/	*phone* [haʊ], [haʊn], [hʌn], *boat* [bʊt],
			[bʊt] *nose* [nod], [nus], [nɛs], *coat* [kʌt]
		/u/	*spoon* [fʊn], *shoes* [tɪs], *boot* [bʊt]
		/aʊ/	*house* [haʊ], [hæs]
		/aɪ/	*kite* [kɪt]
	V	/ʌ/	*bus* [bɑs]
L4-1;9	VV	/i/	*bee* [bi], [bɪ], [bɪʔ], *pea* [pɪʔ], *geese* [dɪʔ],
			sheep [sɛ], *cheese* [ti], [tɪʔ]
			beet [bɪʔ], [bɛʔ], [bɛ], *pete* [piʔ], [pɛʔ]
			teeth [ti], [tɛʔ]
		/e/	*tail* [tɛʔ]
		/ɑ/	*star* [dɑʔ], [dʌʔ], [tʌ], *box* [bɑʔ], [bʌʔ],
			tock [tʌk], *soft* [sʌ]
		/u/	*shoe* [ʃɪʔ], [ʃɪ]
		/aʊ/	*cow* [kʌ], *mouth* [mæ]
	V	/ɪ/	*biz* [bɪʔ], [bi]
C5-1;6	VV	/ɑ/	*top* [dʌk], *doll* [dɑ], [dʌ]
	V	/ɪ/	*sink* [nek]
		/æ/	*gi*__*raffe*__ [dʒoʃ], [ʃɑʃ]
		/ʊ/	*book* [bʌk], [bɑk]
		/ʌ/	*up* [ʌp], [ɑp], *bus* [bʌs], [bɑs]
			duck [gʌk], [gaɪk], [dɑk]
C8-2;0	VV	/o/	*soap* [fob], [fʌb], *phone* [fon], [fʌnd], [fʌn]
		/u/	*food* [fʊd]
	V	/ɪ/	*dish* [dɪs], [dis], *fish* [pɪs], [fis]
			pig [pin], [piŋ], *chick* [kɪk], [kik]
			biz [bɪz], [biz], *kit* [kik]
		/æ/	*cat* [haɪt], [kaɪk], *hat* [haɪt]
			*gi*__*raffe*__ [waɪs], [bɑs], *hands* [haɪn], [haɪnz]
		/ɜ̂/	*bird* [bɝd], [bud]
		/ʌ/	*duck* [gʌk], [gɑk]

[a] Cat, Vowel category: VV, long/tense vowel or diphthong; V, short/lax vowel.

TABLE 3. *Percentages of vowel length errors and codas produced*

Child	No. of tokens	Vowel-length accuracy	Codas produced
L1-1;3	54	80 (43/54)[a]	41 (19/46)
L2-1;3	50	74 (37/50)	70 (26/37)
L3-1;3	12	67 (8/12)	10 (1/10)
L4-1;3	No glossable words		
L1-1;6	169	82 (138/169)	70 (109/155)
L2-1;6	219	90 (197/219)	85 (163/192)
L3-1;6	148	96 (142/148)	62 (67/108)
L4-1;6	8	100 (8/8)	0 (0/8)
C1-1;6	42	86 (36/42)	65 (11/17)
C2-1;6	91	92 (84/91)	14 (10/72)
C3-1;6	123	97 (119/123)	78 (78/100)
C4-1;6	136	77 (105/136)	85 (106/124)
C5-1;6	128	87 (111/128)	74 (85/115)
L1-1;9	369	97 (357/369)	94 (310/331)
L2-1;9	256	98 (252/256)	89 (196/221)
L3-1;9	53	96 (51/53)	94 (47/50)
L4-1;9	177	74 (131/177)	62 (91/146)
L1-2;0	237	96 (227/237)	97 (209/215)
L2-2;0	403	99 (397/403)	95 (332/351)
L3-2;0	272	97 (264/272)	91 (222/244)
L4-2;0	190	91 (173/190)	80 (128/160)
C6-2;0	232	90 (209/232)	79 (139/177)
C7-2;0	190	92 (175/190)	77 (127/164)
C8-2;0	287	87 (250/287)	93 (193/207)
C9-2;0	124	93 (115/124)	20 (21/106)
C10-2;0	188	90 (170/188)	52 (76/147)

[a] Raw scores are listed in parentheses.

tense vowels generally accurately. Their errors included substitutions of the vowels /ɪ/, /ʌ/, and /æ/. Except for L1 and L2 at 1;3, no child exhibited equal frequencies of short for long or long for short vowels.

Relationship between vowel length and coda consonant development. This analysis examines the relationship between vowel length and coda consonant development. In counting codas, we are interested in whether coda position is prosodically marked and not in the accuracy of coda production. Vowel length accuracy is the percentage of times words are produced with the correct target vowel length (short vowels produced as lax) and (long vowels produced as tense or as diphthongs). The prediction is that the percentage of codas produced will be greater than vowel length accuracy.

Columns 3 and 4 of Table 3 list the percentages of vowel length accuracy and coda consonants produced within and across children. Raw scores are listed in parentheses. The main generalization from these results is that both vowel length accuracy and coda production were high across children: L3-1;3 exhibited the lowest percentage of vowel length accuracy (67%); Eight

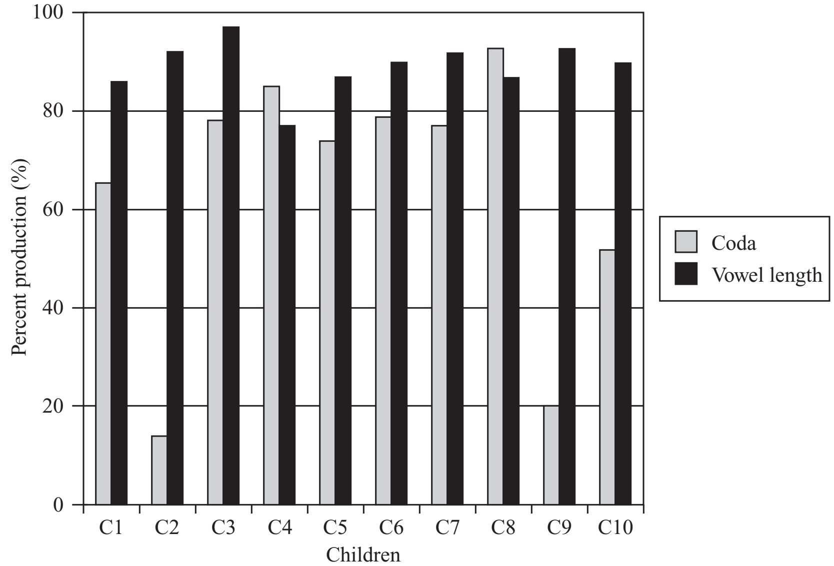

Fig. 3. Percentage coda production and vowel length accuracy in cross-sectional database.

out of 10 children in the cross-sectional database and three out of four children in the longitudinal database (aged 1;6) produced codas in over 50% of target utterances. We now consider the results in more detail, first the cross-sectional and then the longitudinal data. Graphic representations of the data are presented respectively in Figures 3 and 4. Results are not indicated for L4 until 1;9 because of limited data.

In terms of the scenarios discussed above (see Purpose of Study), eight out of the ten children in the cross-sectional database appear to be at the latter stage of rhyme development (see Figure 3). They are producing codas in the majority of target productions (although in the case of C10-2;0, codas are produced only 52% of the time) and are producing the correct target vowel length most of the time. Thus, it seems that they have acquired coda position and vowel length control. Two of the 10 children, however, do not fit the predicted patterns. They are C2-1;6 and C9-2;0 whose coda production was less than 20% while their use of correct vowel length exceeded 90%. Representative examples of these two children's productions are shown in Table 4. Although the high percentage of CV(V) forms suggests that these children are at the earliest stage of rhyme development, the absence of vowel length errors suggests that they are already controlling vowel length. For example, C2 matched the tense and lax vowels in the target words *teeth* and *fish* producing [ki] and [ʃɪ], respectively. She did not produce the lax /ɪ/ in *bib* but still maintained vowel length by producing the lax central vowel /ʌ/

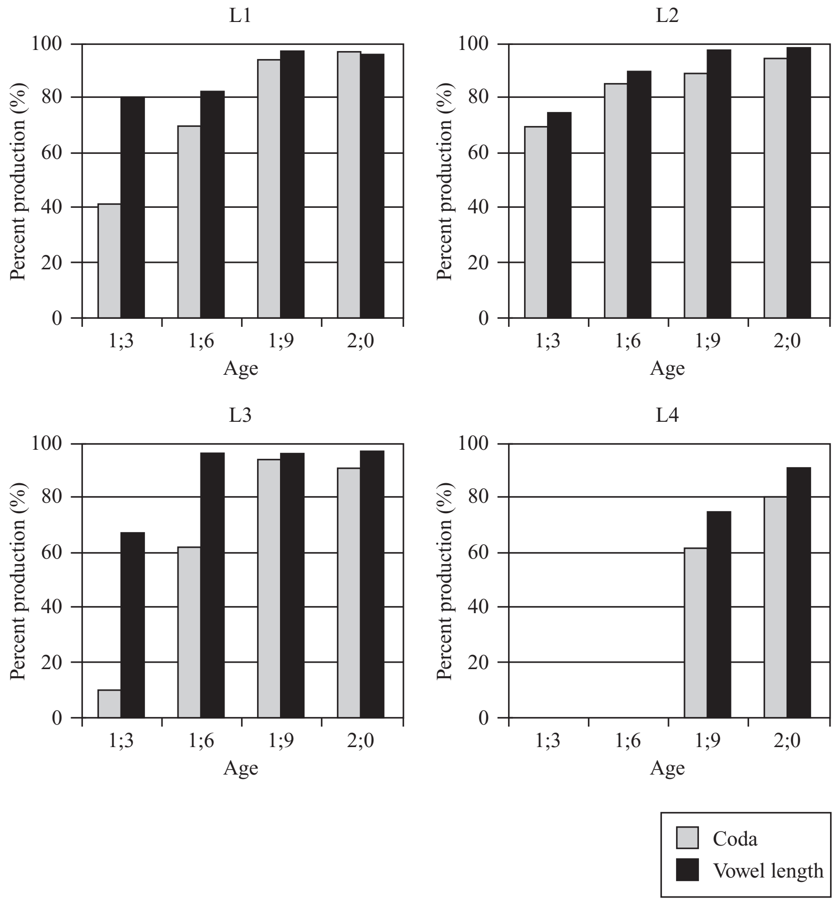

Fig. 4. Percentage coda production and vowel length accuracy in longitudinal database.

(e.g. [bʌ]). Similarly, C9 realized accurately tense and lax vowels in the target words *spoon* and *hat*, producing [bu] and [hæʔ], respectively. He made errors of vowel quality in the words *duck* and *neck* (e.g. [dæ], [dʌʔ]) but still maintained the correct vowel length.

In the longitudinal data set, vowel length and coda acquisition follow predictable developmental trends: the percentages of forms with coda consonants and the correct target vowel length increase across time, as seen in Figure 4. By 2;0, all four children are at the latter stages of rhyme development because vowel length accuracy and coda production is high (greater than 80%). They vary somewhat in their beginning stages of acquisition. At 1;3 months, the two female subjects produced codas quite frequently; 41% of the time in L1's inventory and 70% of the time in L2's

TABLE 4. *Representative examples of two children whose coda production is low and vowel length accuracy is high*

C2-1;6	C9-2;0
shoe [ʃu], [su]	*shoe* [du], [dju]
key [ki]	*key* [gi]
spoon [buː]	*spoon* [bu], [bʷu]
comb [ko]	*bowl* [woʊ]
teeth [ki], [ti]	*pete* [pi], [bi]
mouth [maʊ], [moʊ]	*cheese* [gi], [di]
nose [no], [wo]	*mouse* [boʊ], [maʊ]
book [bʊ]	*gum* [gʌ]
bib [bʌ]	*duck* [dæ]
fish [ɪs], [ʃɪ]	*stuck* [gʌ]
duck [dʌ], [dʌʔ]	*hat* [hæʔ]
sun [sæ]	*neck* [dʌʔ]
hat [hæ]	*bath* [bæʔ]

inventory. Additional data from L2 at 1;0 revealed that codas were present in five out of her eight glossable words (e.g. *dog* [bɛk]; *up* [ʌp]; *fish* [bɪʔ]), suggesting that if there were a core-syllable stage in this child's development, it was extremely early and short. Subject L3 produced very few glossable words until he was 1;6 and Subject L4, not until he was 1;9. At these sessions, codas were present in over 60% of target words. Similar to the findings in the cross-sectional study, the percentage of vowel length accuracy was relatively high even at 1;3 for most children. Subject L3-1;3 did produce one third of his glossable words (n = 12) with vowel length errors, but at this stage he produced also very few codas (10%).

Based on these results, there is little evidence that coda consonant development precedes acquisition of the vowel length contrast. If anything, children seem to control vowel length earlier than coda position, as suggested by the patterns of the two children in the cross-sectional data-set who produced very few coda consonants yet made few vowel errors. The next section examines coda inventories across children.

Coda consonant development. Table 5 presents coda consonant inventories across children.[5] Coda consonants are categorized according to four manner

[5] It should be noted that reduced coda consonant inventories did not reflect reduced consonant inventories in general. C2-1;6, C9-2;0, and L4-1;9, who produced very few coda consonants, had relatively rich consonant inventories containing the three manner classes, stops, fricatives and nasals. In addition, C5-1;6 and L4-2;0, who did not produce voiced obstruents as codas, produced voiced and voiceless obstruents in other syllable positions. The only exceptions were the three children in the longitudinal study whose consonant inventories were limited at the earliest recording session. L1-1;3 produced [b, d, m, w, h] in syllable-onset position and [p, ʔ] in coda position; L2-1;3 produced [b, d, g] in onset and [p, t, k, ʔ] in coda; L3-1;3 produced [b, d] in onset and [p] in coda.

TABLE 5. *Coda consonant inventories*

Child	% Coda production	Coda inventories: Stops	Frics	Nasals	Liq
L1-1;3	41	p, ʔ			
L2-1;3	70	p, t, k, ʔ			
L3-1;3	10	*p[a]			
L4-1;3	No glossable words				
L1-1;6	70	p, t, k	f, s, ʃ, tʃ		
		b	ʒ		
L2-1;6	85	p, t, k, ʔ	s, ʃ, tʃ, ç	m, n, ŋ	r
		g	z, ʒ		
L3-1;6	62	p, t, k, ʔ			
L4-1;6	0				
C1-1;6	65	t, k, ʔ			
C2-1;6	14	ʔ	s		
C3-1;6	78	p, t, k, ʔ	f, s	n, ŋ	r
		d, g			
C4-1;6	85	p, t, k, ʔ	f, s, ʃ, tʃ	m, n	
C5-1;6	74	p, t, k	s, ʃ	n	
L1-1;9	94	p, t, k, ʔ	f, s, ʃ, tʃ	m, n, ŋ	r
		b, d, g	z		
L2-1;9	89	p, t, k, ʔ	f, θ, s, ʃ	m, n	r
		b, d, g	v, z		
L3-1;9	94	p, t, k, ʔ	s	n	
		g	z		
L4-1;9	62	ʔ			
L1-2;0	97	p, t, k, ʔ	f, θ, s, ʃ	m, n, ŋ	r
		b, d, g	v, z		
L2-2;0	95	p, t, k, ʔ	f, θ, s, tʃ	m, n, ŋ	r, l
		b, d, g	v, z		
L3-2;0	91	p, t, k	f, s, ʃ, ç	m, n, ŋ	r, l
		b, d, g	v, z, dʒ		
L4-2;0	80	p, t, k	s, ʃ	m, n, ŋ	r
C6-2;0	79	p, t, k, ʔ	f, s, ʃ	m, n, ŋ	
		b, g			
C7-2;0	77	p, t, k, ʔ	f, s	m, n	
		d, g	z		
C8-2;0	93	p, t, k	s, ʃ, tʃ	n, ŋ	r
		b, d	z, dʒ		
C9-2;0	20	p, ʔ		m	
C10-2;0	52	p, k, ʔ	s, ʃ, ç		r
			z		

[a] All coda segments occurred at least twice in each child's inventory with the exception of L3-1;3 in which only one coda consonant was attested.

classes: stops, fricatives, nasals, and liquids and only those consonants which were produced at least twice in a given child's corpora are listed, with the exception of L3-1;3 who produced only one word with a coda consonant. This is indicated by an asterisk in Table 5. Accuracy is not taken into consideration; the production [tʃis] for *cheese* would be noted as an example in which the child produced the coda [s] even though the target coda was /z/. This analysis should be seen as an approximate guide to children's coda acquisition because not all coda types were equally sampled in the database. There was an overall bias towards obstruent rather than sonorant codas in the target words appearing in the database and in addition, children varied in terms of which targets words they produced, reflecting either selection and avoidance strategies or simply chance factors with word preferences.

The analysis shows that the earliest and most commonly occurring manner class in children's coda inventories was voiceless stops. For example, L1-1;3, L3-1;3, and C1-1;6 produced voiceless stops as their first coda consonants. There was variability, however, in this pattern; C2-1;6 produced [s] as her first true (i.e. non-glottal) coda and C9-2;0 produced both [p] and [m], perhaps, suggesting a preference for labial codas. It is difficult to determine from the data what is the next manner class acquired because voiceless fricatives seem to be present in children's inventories around the same time as nasals (see C4-1;6 & C5-1;6). Two children (L1-1;6 & C10-2;0) produced fricatives and not nasals and one child C9-2;0 produced nasals and not fricatives, providing little evidence for the acquisition of one class over another. Following voiceless fricatives and nasals, voiced obstruents (stops & fricatives) and the liquid /r/ were the next codas acquired. /l/ was the target sound that produced the most difficulty as coda and was not attested in most children's inventories.

One of the most salient findings from the coda analysis was that voiced obstruents generally appeared in coda position after voiceless obstruents and (in many cases) nasals. This pattern can be seen in the examples of Subjects C5-1;6 and L4-2;0, who did not produce any voiced obstruents but did produce voiceless obstruents and nasals (3a & b). Voiced obstruents were either substituted by voiceless obstruents or were deleted.

(3)

Coda production in C5-1;6 and L4-2;0

Targets ending in voiceless obstruents and nasals		Targets ending in voiced obstruents	
a. C5-1;6			
soap	[doʊp]	*bib*	[bɛ]
feet	[bit]	*slide*	[daɪ]
sock	[kɑk], [gɑk]	*dog*	[dɑ]
goose	[gos]	*cheese*	[tʃis], [diç]
dish	[dɪtʃ]	*shoes*	[dus], [duʃ]
spin	[bʌn]		
b. L4-2;0			
sheep	[ʃip], [tʃip]	*bib*	[bɪp]

light	[waɪt]	*bead*	[biː], [bit]
sock	[sʌk]	*pig*	[pɛk], [pɪk]
geese	[gis]	*cheese*	[tis], [tʃiʔ]
fish	[fɪs], [fɪʃ]	*biz*	[bɪs], [bæs]
down	[daʊn]		
farm	[sɑm]		

Bimoraic size constraint. Finally, we examine whether there is evidence for a size restriction in early syllable development. According to Fikkert (1994) and Demuth & Fee (1995), children pass through a stage in syllable structure development in which rhymes are minimally and maximally bipositional or bimoraic. One way of investigating this is by examining the percentage of consonants produced after short versus long vowels. If children are subject to a bimoraic size restriction, greater percentages of consonants will be produced after short than long vowels. This is assuming that children have acquired a vowel length distinction. The previous analyses have already indicated that the majority of children in the cross-sectional and most children by 1;6 in the longitudinal study make very few vowel length errors. Thus, for the time being, we assume that all children have acquired a vowel length distinction.

Table 6 displays the percentage of codas produced across target forms with long and short vowels in the cross-sectional and longitudinal databases. With few exceptions, children produced codas more frequently in target forms with short vowels. Paired t-tests established that these differences were significant both for the cross-sectional ($t(9) = 4{\cdot}3$; $p = 0{\cdot}002$) and longitudinal databases ($t(3) = 8{\cdot}5$; $p = 0{\cdot}003$).[6] Thus, there does appear to be evidence that children's coda production is sensitive to vowel length or syllable size[7].

To determine the extent of syllable size restrictions, we examine the

[6] Coda production data for the longitudinal database were based on a mean score across all four sessions (2 sessions in the case of subject L4). Analyses in which proportion scores were arcsine transformed to correct instability of error term variances resulted in identical findings.

[7] Fikkert's claim that the rhyme is bipositional is dependent upon additional observations pertaining to vowel length and whether the coda consonant is sonorant or obstruent. Children in her study produced sonorant codas more frequently after short than long vowels but did not display the same pattern with obstruent codas. We do not evaluate the specifics of Fikkert's claim here, because we do not have equal numbers of sonorant and obstruent codas in the database. A cursory examination of the data suggests, however, that children produced codas more frequently after short vowels regardless of whether the coda was sonorant or obstruent. Salidis & Johnson's (1997) analysis initially suggested that children produced codas more frequently after short than long vowels. However when they took into consideration the uneven proportion of liquids in the data, this difference disappeared. Additional analysis of our data showed that there were no differences in the distribution of manner of articulation of coda consonants in the two databases which could have accounted for the significant effect on coda production.

TABLE 6. *The percentage of codas produced across target forms with long and short vowels*

Child	Vowel in target form	
	VV[a]	V
L1-1;3	6 (1/18)[b]	64 (18/28)
L2-1;3	52 (12/23)	100 (14/14)
L3-1;3	0 (0/4)	17 (1/6)
L4-1;3	No glossable words	
L1-1;6	61 (54/88)	82 (55/67)
L2-1;6	78 (83/107)	94 (80/85)
L3-1;6	49 (32/65)	81 (35/43)
L4-1;6	No codas produced	
C1-1;6	44 (4/9)	88 (7/8)
C2-1;6	7 (3/42)	23 (7/30)
C3-1;6	70 (48/69)	97 (30/31)
C4-1;6	81 (54/67)	91 (52/57)
C5-1;6	70 (53/76)	82 (32/39)
L1-1;9	89 (162/183)	100 (148/148)
L2-1;9	83 (101/121)	95 (95/100)
L3-1;9	91 (21/23)	96 (26/27)
L4-1;9	50 (38/76)	76 (53/70)
L1-2;0	96 (109/114)	99 (100/101)
L2-2;0	92 (182/198)	98 (150/153)
L3-2;0	87 (119/137)	96 (103/107)
L4-2;0	68 (66/97)	98 (62/63)
C6-2;0	72 (73/102)	88 (66/75)
C7-2;0	77 (79/102)	77 (48/62)
C8-2;0	92 (131/143)	97 (62/64)
C9-2;0	14 (10/70)	31 (11/36)
C10-2;0	45 (45/99)	65 (31/48)

[a] VV, long/tense vowel or diphthong; V, short/lax vowel.
[b] Raw scores are listed in parentheses.

percentage of productions which are sub-minimal (monomoraic), minimal (bimoraic), and supra-minimal (greater than bimoraic) for the target form (C)VVC. Again, we assume that lax vowels in the output are monomoraic and tense vowels and diphthongs are bimoraic. Results are presented in Table 7. To make the table easier to read, the predominant production forms (i.e. > 30%) for each child are highlighted in bold.

If children are at the minimal word stage of development, they should produce the majority of their attempts at (C)VVC targets as minimal forms. Table 7 indicates that several children are clearly beyond the minimal word stage because they produced greater than 60% of their (C)VVC targets as supra-minimal productions. They are C3-1;6, C5-1;6, C6-2;0, C7-2;0, C8-2;0 in the cross-sectional data-set and L1-1;9, L2-1;6, and L3-1;9 in the longitudinal data-set. Other children (C4-1;6, C10-2;0; L1-1;6, L3-1;6,

TABLE 7. *Percentages of sub-minimal, minimal, and supraminimal productions for (C)VVC targets*

Child	No of tokens[a]	Child productions Sub-	Min.	Supra-
L1-1;3	18	17	**83**	0
L2-1;3	24	4	**75**	21
L3-1;3	4	**75**	25	0
L4-1;3	No glossable words			
L1-1;6	88	4	**40**	**56**
L2-1;6	107	0	28	**72**
L3-1;6	65	0	**54**	**46**
L4-1;6[b]	8	0	**75**	25
C1-1;6	9	0	**89**	11
C2-1;6	42	2	**88**	10
C3-1;6	69	0	**32**	**68**
C4-1;6	67	1	**63**	**36**
C5-1;6	76	3	**33**	**64**
L1-1;9	183	1	11	**88**
L2-1;9	122	0	17	**83**
L3-1;9	23	0	0	**100**
L4-1;9	76	9	**70**	21
L1-2;0	115	0	5	**95**
L2-2;0	98	0	9	**91**
L3-2;0	137	0	13	**87**
L4-2;0	97	1	**46**	**53**
C6-2;0	102	1	**34**	**64**
C7-2;0	105	0	27	**73**
C8-2;0	147	0	14	**86**
C9-2;0	70	3	**83**	14
C10-2;0	99	2	**67**	**31**

[a] Number of productions of (C)VVC targets.
[b] Limited data, see footnote 3.

L4-2;0) produced more than one third of their (C)VVC targets as supra-minimal indicating that they were also moving beyond a size restriction. Children who produced the majority of (C)VVC targets as minimal forms include L1-1;3, L2-1;3, C1-1;6, C2-1;6, L4-1;9, and C9-2;0. Two of these children (C2-1;6, C9-2;0), however, produced very few coda consonants (see Tables 1 & 2) resulting in a large percentage of sub-minimal productions for (C)VC targets. C1-1;6 was the sole child in the cross-sectional database and L1 and L2 at 1;3 and L4 at 1;9 were the children in the longitudinal database who produced mainly bimoraic forms. L3 at 1;3 produced his few identifiable words with lax vowels and without coda consonant (in 9 out of 10 cases) resulting in sub-minimal productions for both (C)VC and (C)VVC targets. By 1;6, he was already producing coda consonants and making few vowel length errors, resulting in a high percentage of supra-minimal forms for (C)VVC targets. Thus, our database did not document a particular stage of bimoraicity for this child.

In sum, the findings of Table 7 indicate that only C1-1;6, L1 and L2 at 1;3, and L4 at 1;9 produced predominantly bimoraic forms for CVVC targets. The analysis of vowel patterns, however, indicated that these very same children exhibited some degree of vowel length variation, suggestive of a lack of vowel length control. Therefore, it is difficult to know how to interpret these children's findings in terms of moraic consistency. If these children do not represent vowel length, then the results of Table 7 are invalid for these children, since in doing the calculations, we assumed that vowel length was controlled. If, instead, these children represent all vowels with a monomoraic nucleus, output forms for CVVC targets would be both subminimal (i.e. CV(V)) and minimal (i.e. CV(V)C), depending upon the production of coda consonants. The other possibility is that these children are in the process of acquiring vowel length, and the vowel length variation documented in Tables 1 and 2 is indicative of the trading effects in syllable structure noted by Demuth & Fee (1995). Some examples are given in (4).

(4) Vowel length variation consistent with bimoraic size restriction

C1-1;6	*ball*	[bɔ], [bʌʔ]
L1-1;3	*ball*	[bɑ], [bʌʔ]
	eye	[ɑɪ], [æʔ]
L2-1;3	*dog*	[dɑ], [dʌk]
L4-1;9	*teeth*	[ti], [tɪʔ]
	cheese	[ti], [tɪʔ]
	biz	[bi], [bɪʔ]

An additional way of verifying whether these children are at the minimal word stage is to examine their productions of disyllabic targets. Given a bimoraic size restriction, disyllabic targets should also be produced as minimal forms. Examples of productions of disyllabic targets are given in (5).

(5) Productions of disyllabic targets by selected children

C1-1;6	*baby*	[bɪbi], [bebi], [bebiː]
	kitty	[dɪdi], [gɪki], [gi]
	button	[bɑti], [pɑti], [bʌdi]
L1-1;3	*baby*	[bebi], [be], [bi]
L2-1;3	*baby*	[bebe], [bebi]
	kitty	[kɛki], [kɪʔ], [ki], [ke]
	tigger	[tɛgʌ], [dɛgo], [dɪgʌ]
L4-1;9	*baby*	[bebɪ], [bibi], [nebi]
	doggie	[daɪ]
	dirty	[dɪʔ]

The examples in (5) show that, on several occasions, children truncated disyllabic words to monosyllables (e.g. C1-1;6 produced *kitty* as [gi]; L1-1;3 produced *baby* as [bi]) or displayed alternations between both lax and tense vowels in their disyllabic productions (e.g. C1-1;6 produced target /e/ as [e] or [ɪ] in BABY: [bebi], [bɪbi]). Under the assumption that these children do not control vowel length, some of the monosyllabic forms would be sub-minimal and the disyllabic forms would be minimal. Under the assumption that these children do control vowel length, the monosyllabic and some of the disyllabic forms (e.g. L2's production of *tigger* [tɛgʌ]) would be minimal and some of the disyllabic forms would also be supra-minimal (e.g. L2's production of *baby* [bebe]). In sum, all that can be said is that, some of the time, children showed an awareness of minimal forms in their disyllabic productions.

DISCUSSION

This study investigated rhyme development in English focusing on children's acquisition of the vowel length contrast and acquisition of codas. The results of this study addressed several claims from Fikkert's (1994) parametric theory of syllable structure and Demuth & Fee's (1995) theory of children's early word shapes, namely, that children make errors of vowel length in early phonological acquisition, that children produce coda consonants before they acquire the vowel length distinction, that children acquire obstruents before sonorants in coda position, and that there is a period in development when children's rhymes are minimally and maximally bipositional or bimoraic. First, we summarize the major findings of the study.

Vowel-length contrast

Our results indicated that the English-speaking children in this study did not make a high percentage of vowel length errors. We measured vowel length errors in two different ways: 1. by examining alternations between long and short vowels in multiple productions of the same target form; and 2. by counting substitution errors across all target forms. Considering the first analysis, isolated examples of vowel length alternations were present in the inventories of most children, particularly with the tense/lax cognates /i/ and /ɪ/ and between the low vowels /æ/ and /ɑ/ and the central vowel /ʌ/. Some of the youngest children in the study (C1-1;6, L1-1;3, L2-1;3) manifested several instances of vowel length variation, suggestive of a lack of vowel length contrast; however, the majority of children in the cross-sectional study and all children in the longitudinal study, except L1 and L2 at 1;3, displayed few vowel length alternations.

When counting vowel length errors across all targets, some children were observed to display consistent long/short substitutions. For example, two children produced certain tense vowels and diphthongs as lax (C4-1;6; L4-1;9), and two children produced certain lax vowels as tense (C5-1;6, C8-2;0). Interestingly, no child made a significant number of substitution errors with both tense and lax vowels at the same time. Fikkert (1994) also noted that her subject Jarmo preferred one vowel group over another; he was more prone to lengthen short vowels than shorten long vowels. She argued that this pattern was not necessarily a contra-indication to a lack of vowel length control, because Jarmo's preference for long vowels may have reflected the higher frequency of target forms with long vowels or the fact that long vowels appear only in open syllables in Dutch. In this study, most children's datasets contained a higher percentage of target forms with long than short vowels; yet, children who did make vowel errors did not all display a tendency for substituting short with long vowels. As indicated, some displayed a tendency for substituting long with short vowels in spite of the higher frequency of target forms with long vowels in the target set. Given that these children achieved the correct target vowel length most of the time, and that their vowel errors were restricted to one category of vowels only (long or short) and often to certain vowels, these substitution patterns are not strongly suggestive of a lack of vowel length contrast.

Relationship between coda development and vowel length

Our analyses found no support for the claim that coda development precedes acquisition of the vowel length distinction. Indeed, the overwhelming finding of the study was that this set of children (n = 14) made few vowel length errors, whereas they displayed variability in their coda production. A finding particularly problematic for Fikkert's (1994) and Demuth & Fee's (1995) account was the patterns of two children (C2-1;6, C9-2;0) who were at an early stage of coda consonant development yet appeared to control vowel length. In the case of these children, coda consonant development did not precede vowel length control. In the case of other children in the database, it is difficult to say what preceded what (coda or vowel length development). The current findings seem to indicate, however, that vowel length is acquired early in phonological acquisition (at least in English), whereas coda acquisition may vary on a child-to-child basis.

Coda consonant development

The analysis of coda segments revealed consistent trends in children's coda development. Our findings concur with Fikkert's in showing that the first codas are generally obstruents, but diverge from Fikkert's in finding little support for a simplified pattern of obstruent before sonorant acquisition. Our results are consistent with several other sources in English which report that final voiced obstruents are acquired after final voiceless obstruents and nasals (Stoel-Gammon, 1985; Bernhardt & Stemberger, 1998). This pattern of acquisition would not be apparent in Dutch because like German, Dutch has no voicing contrast for obstruents in word-final position.

The fact that English-speaking children readily produce obstruents as codas is consistent with sonority constraints on moras in English which allow obstruents as moraic segments (Zec, 1995). Nevertheless the order of coda acquisition does not support the universal preference for sonorants over obstruents in coda position. Because there are languages which allow only sonorant consonants as codas and sonorant consonants as moraic, we might predict that some children will pass through an intervening stage, in which sonorant but not obstruent codas are produced. This pattern was not observed in the current dataset. Fikkert (1994) proposes that by producing obstruents first as codas, children are striving for a maximal sonority contrast between nucleus and coda. Bernhardt & Stemberger (1998) note that coda consonants are subject to constraints requiring them to be both consonant-like (or margin-like) and vowel-like (or rhyme-like) at the same time. The earlier appearance of consonants with default manner features (e.g. voiceless stops) is consistent with a tendency for margin-like segments in the coda. Associated with this is a restriction on certain non-default features in codas, in particular, voicing of obstruents. This production pattern no doubt reflects phonetics (aerodynamics) of voicing and perceptual factors which operate differently according to syllable position, making it more difficult for a child to produce an acceptable sounding voiced stop in coda than onset position (Smith, 1979; Stoel-Gammon & Buder, 1999). The later acquisition of voiced stops in English is thus consistent with the marked pattern of voiced obstruent codas in adult languages.

Bimoraic size constraint

The findings indicated that children produced coda consonants significantly more frequently after short than long vowels.[8] One interpretation of these results is that children produced codas more frequently after short vowels in

[8] The question could be posed here, whether there are alternative explanations of the data. Could input frequency effects, such as the ratio of short to long vowels in the data set, influence the results on coda production? In the current database, children had more opportunities to produce target words containing long vowels with codas than short vowels with codas. Target syllables with short vowels represented 42% of the total number of closed target syllables. We do not know, however, whether the ratio of short to long vowels in closed syllables in the current data-set reflect those of the ambient language. An anonymous reviewer also queries whether articulatory constraints (a consonant is easier to produce after a short than long vowel) may be responsible for the current finding. An answer to this question goes beyond the current bounds of this study. Interestingly, when we separated the group of long vowels into tense vowels and diphthongs, children showed no greater tendency to omit codas after diphthongs than after tense vowels, despite the fact that diphthongs are phonetically longer than tense vowels (at least in adult speech). This result seems to suggest that the omission of codas after long vowels was not the result of a phonetic length effect.

order to satisfy a bimoraic size constraint and they produced codas less frequently after long vowels, either because their syllable template could only accommodate two moras and/or because they had not learnt that additional elements in the rhyme could be extra-rhymal and not contribute to syllable weight. It should be noted that the production of minimal forms came about predominantly through the presence or absence of codas and not through changes in vowel length. Alternations between closed syllables with short vowels and open syllables with long vowels for the same target form were relatively uncommon in the current data-set (with the exception of examples given in (4)).

Although our findings support a bimoraic constraint as a general tendency in acquisition, the majority of our subjects were beyond the minimal word stage of acquisition as suggested by the high percentages of supra-minimal forms for CVVC targets. This suggests that the bimoraic constraint as an absolute upper-limit on output occurs for a very short time at the earliest stages of acquisition. In addition, two children in the cross-sectional database (e.g. C2-1;6, C9-2;0) produced a high proportion of CV and CVV forms. Given that these two children matched target vowel length most of the time, their CV forms must be interpreted as monomoraic at a developmental stage when sub-minimal forms should have been prohibited.

Because the current findings on the acquisition of vowel length are at odds with the theoretical claims of Fikkert (1994) and Demuth & Fee (1995), we explore reasons for the disparate findings. We conclude with a discussion of the relevance of these findings to syllable structure development in English.

Further exploration of vowel length acquisition

One possible reason for the early acquisition of the vowel length distinction in English is that long and short vowel pairs vary not only in quantity but also in quality and the quality distinction may be particularly salient. This statement leads to several avenues of pursuit: 1. that it would be interesting to study acquisition of vowel length in languages in which phonological vowel length is based predominantly upon quantity (phonetic length), and 2. that it would be useful to consider other types of vowel length differences which children acquire apart from tense versus lax, for example, phonetic length distinctions. To address these issues, we review briefly findings on the acquisition of intrinsic and extrinsic vowel length in Swedish and English.

Vowel length acquisition in Swedish and English

Swedish has a rich vowel inventory, which contains nine short-long vowel pairs, although minor quality differences in each pair do exist. Stoel-Gammon and colleagues have measured duration and formant frequency values of Swedish- and American English-speaking children's vowel productions at 2;0 and 2;6, in particular, of the vowels /i/ and /ɪ/ (Stoel-

Gammon, Buder & Kehoe, 1995; Stoel-Gammon & Buder, 1998). They found that Swedish-speaking children as young as 2;0 distinguished long and short vowels on the basis of duration (i.e. produced long vowels with greater duration than short vowels), whereas English-speaking children produced tense and lax vowels with similar durations. In contrast, they found little difference in formant frequency values between the Swedish vowel productions but large differences in the English-speaking children's productions of the tense and lax vowels /i/ and /ɪ/. This finding supports our hypothesis that quality is the most salient cue in the distinction of tense and lax vowels for English-speaking children, and only later in acquisition, do children learn that phonetic length differences are involved. This finding does not mean, however, that English-speaking children are unable to control vowel duration. Stoel-Gammon & Buder (1998) found that the same children who did not make intrinsic vowel length differences (i.e. distinguish tense vs lax vowel pairs in terms of duration) were already making strong differences in extrinsic vowel length; vowels before target voiced stops were longer than before target voiceless stops, suggesting that other phonetic aspects of vowel length were being learnt.

Although these data do not shed light on the rate of development of different aspects of the rhyme, they indicate that, in languages with true phonemic vowel length, children are likely to acquire vowel length control relatively early. Similarly, Ota (1999) in studying acquisition of the vowel length distinction in Japanese, found that all three of his Japanese-speaking subjects (aged approximately 1;6) showed significant durational differences between long and short vowels, although the quantitative realization was not as extreme as in adult Japanese. Interestingly, one of the Swedish children in Buder, Crary & Stoel-Gammon's (1998) study, who did not exhibit language-appropriate vowel length differences, showed significant quality differences, suggesting that in the early stages, children may use one cue or the other to mark the distinction between long/short or tense/lax vowel sets.

Given that children are controlling vowel length (or tense/lax contrast) early in languages such as English and Swedish, it is surprising that Fikkert found vowel length to be acquired late in her Dutch-speaking subjects. As previously mentioned, Dutch, like English, is a language which contains tense and lax vowels and a phonological length distinction not solely based on phonetic length. Therefore, we would have expected similar developmental findings in vowel length in Dutch and English. Language-specific features (phonological and phonetic) of the Dutch vowel system may explain the later acquisition. First, the vowel length contrast exists only in closed syllables and all open syllables are phonologically light, in contrast to English, which contains both heavy and light open syllables (Salidis & Johnson, 1997). As hypothesized by Fikkert, it may be necessary for children to first produce closed syllables before they can learn the vowel length distinction, because this is the context in which the length contrast manifests. In addition, Dutch may fall in between Swedish and English in terms of the saliency of quantity and quality cues. That is, the salient quantity differences between long and short Swedish vowels and the salient quality differences between tense and lax English vowels may lead to early acquisition of the contrast. Indications that a somewhat different situation exists in Dutch comes from an acoustic analysis of vowel contrasts by Clement & Wijnen (1994), who show that two-year-old children make neither significant formant frequency nor durational distinctions for the long/short vowel pair /a, ɑ/. Their acoustic results were corroborated by informal observations of spontaneous speech, indicating that a listener would have difficulty determining whether a two-year-old had pronounced /a/ or /ɑ/. This finding is consistent with Fikkert's results, based on transcriptional data, that Dutch-speaking children around the age of two years do not control vowel length.

Finally, if indeed English-speaking children initially distinguish tense and lax vowels through quality and not through phonetic length, it could be argued that they don't actually have an underlying vowel length distinction; that is, they don't know that tense vowels represent two moras and lax vowels, one. They may proceed through an intervening stage of development, in which the tense/lax (quality) contrast is acquired but the corresponding phonetic and phonological length distinction is not acquired. There are two findings which indicate this does not seem to be the case. First, phonologically long vowels comprise not only tense vowels but also diphthongs, and diphthongs in this study were rarely subject to substitution errors. Out of a total of 425 productions of monosyllabic words containing diphthongs, only 8 times (2% of cases) did children produce a lax vowel instead of a diphthong; only 21 times (5% of cases) did children produce a tense vowel instead of a diphthong. If children are able to produce two different melodic elements, then it can be surmised that they have access to two skeletal slots and, by association, a branching or bimoraic nucleus. Second, it is hard to explain the different production rates of consonants after short versus long vowels if children do not have an underlying length distinction. In our longitudinal data, children produced greater percentages of consonants after short than long vowels even from the earliest data collection sessions (i.e. at 1;3), consistent with the different representation of long and short vowels. Similar data (increased production of codas after short vowels and increased omission of codas after long vowels) led Fikkert to surmise that Jarmo had acquired an underlying length distinction, although in the case of Jarmo it was at a later developmental stage than the English-speaking children in the current study.

Nevertheless to truly determine whether children have an underlying vowel length distinction, we must also examine whether long and short vowels behave differently in phonological processes which depend on this distinction, such as stress assignment (see Salidis & Johnson, 1997, p. 12 n. 9). Unfortunately, there is not much data that can be brought to bear on this because the children in the present study did not spontaneously produce sufficient numbers of multisyllabic words to allow examination of the quantity-sensitivity rule of English stress. Kehoe (1998), in a separate study, showed that English-speaking children as young as 1;10 displayed a tendency to shift primary stress to syllables containing long vowels and diphthongs; for example, 'crocodile' was produced as [ʔækuʔáʊ] and 'telephone' was produced as [tɛ̀lfóː] suggesting an awareness of quantity differences within syllables. Findings such as these indicate that acquisition of quantity-sensitivity may occur relatively early in English, consistent with the early acquisition of the vowel length contrast, and differ from the developmental schedule currently proposed for Dutch.

Syllable structure development

Our findings support those of Salidis & Johnson's (1997) in indicating very little developmental change in certain aspects of syllable structure. Children controlled the long-short distinction early in production and in several cases, codas were present from the earliest recorded session. To account for those children who did not produce codas early, we propose a different order of syllable structure acquisition for English-speaking children than the one currently proposed for Dutch- and English-speaking children. Some children (such as C2-1;6 and C9-2;0) acquire the vowel length contrast before coda consonants (i.e. branching nuclei before rhymes). As discussed, language-specific differences between Dutch and English, such as the vowel length to weight relationship and the relative salience of quantity versus quality cues, may lead to differences in the order of acquisition.

As for why codas are produced early by some English-speaking children, lexical frequency appears to be an important factor. Stoel-Gammon (1998), in analysing the phonological characteristics of approximately 600 early acquired words from the MacArthur Communicative Developmental Inventories (CDI), found the most common target syllable shape to be CVC, far exceeding the frequency of CV and CVCV forms. Cross-linguistic studies show, as well, that the relative frequency of codas in the target language influences children's babbled productions (de Boysson-Bardies, Vihman, Roug-Hellichius, Durand, Landberg & Arao, 1992; Lleó, El Mogharbel & Prinz, 1994), thus, making it not surprising that codas are present in some English-speaking children's first words.

Despite the early marking of codas, the proportion of codas and the size of the segmental inventory were clearly subject to developmental trends. We know also that other aspects of syllable structure, in particular, clusters in onset and coda position manifest stage-like development (Fikkert, 1994; Lleó & Prinz, 1996, Barlow, 1997). Most children pass through a stage of simple before complex onsets and codas, and complex codas typically emerge before complex onsets (Salidis & Johnson, 1997). These aspects of syllable structure are outside those examined in the current study, but nevertheless highlight that the development of prosodic structure is a vital topic in phonological acquisition.

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APPENDIX

EXAMPLES OF THE STIMULUS WORDS

Monosyllables

ball, bead, bear, bee, beet, bib, big, 'Biz', bird, blue, boat, book, boot, bowl, box, cake, car, cat, chair, cheese, chick, clock, comb, cow, cup, 'D', dig, dish, dog, doll, door, down, duck, 'Dude', eye, face, feet, fish, frog, geese, goose, green, hat, head, house, juice, key, keys, 'Kit', knee, mouth, nose, one, paw, paws, pea, peas, 'Pete', phone, pie, piece, pig, plate, 'Poo' (Winnie), sheep, ship, shoe, shoes, sit, soap, sock, soup, snake, spoon, sun, tail, tea, tie, tock, toe, toes, top, toy, toys, two, watch, whale.

Disyllables

apple, baby, bottle, bunny, cookie, doggy, hammer, kitty, monkey, potty, puppy, tiger, 'Tigger', tissue.