Children's Productions of Multi-Syllabic Lexical Stress Patterns in Different Prosodic Positions

Irina A. Shport

Linguistics Department, University of Oregon, Eugene, Oregon 97403-1290 USA

ishport@uoregon.edu

Abstract

Production of lexical stress patterns in bi- and tri-syllabic words by five-year-old children was investigated. Duration and amplitude, which are the primary acoustic correlates of lexical stress in American English, were examined in words produced in isolation, in utterance-initial and utterance-final positions. In all three prosodic environments, children and adults differentiated lexical stress patterns by varying relative rhyme durations in the words. The difference between children and adults was observed in amplitude patterns within each word type. The amplitude patterns of adults varied as a function of prosodic position, whereas children tended to have similar amplitude patterns in words produced in isolation and in utterance-final position. These results suggest that the position of a word in an utterance influences the inter-syllabic amplitude pattern in the word. Children may acquire amplitude patterns in utterance-final words later than in utterance-initial words, possibly due to a larger degree of pattern variation in the former rather than the latter position.

Index Terms: child speech, lexical stress patterns, prosodic position, duration, amplitude

1. Introduction

The acquisition of lexical stress patterns by English-speaking children has been extensively studied in bi-syllabic words. Previous research indicates that children acquire lexical stress early [1, 2], as some studies suggest by the age of two [3]. The strong-weak pattern of trochees is learned earlier than the weak-strong pattern of iambs [3, 4]. However, little is known about the acquisition of lexical stress patterns in tri-syllabic words or about the effect of the word position in a prosodic unit on the realization of lexical stress patterns in children's speech. The goal of this study is to fill this gap.

In adults' speech, prosodic position affects the duration patterns of words varying in their lexical stress specification. For example, final lengthening related to prosodic boundary occurs mostly in the phrase-final syllable rhyme, but it is also significant in the main-stress rhyme when the phrase-final and main-stress rhymes do not coincide [5]. Thus, rhyme durations in the same word would systematically vary when the word occurs in the utterance-initial or utterance-final position.

In addition to duration, amplitude is also an acoustic correlate of lexical stress in English [6, 7]. Some work suggests that although very young children mainly use duration to signal lexical stress, they consistently use both duration and amplitude by age three or four [1]. Prosodic position may also affect the amplitude patterns of words varying in their lexical stress [8].

Since duration and amplitude correlates of lexical stress are likely to have different courses of development in first-language acquisition, it is possible that children and adults will implement duration and amplitudes patterns differently in their productions of multi-syllabic words. This paper addresses two questions:

(1) Do children's duration and amplitude patterns differ from adults?

(2) Are these patterns influenced by the word position in a prosodic unit?

To answer these questions the acoustic correlates of lexical stress were analyzed in child and adult productions of two- and three-syllable words in three prosodic positions (isolation, utterance-initial, utterance-final). Children of the pre-school age were selected for this study as they were likely to be comfortable creating sentences of different configurations.

2. Methods

2.1. Participants

Eleven children and twelve adults participated in the study. The participants were monolingual native speakers of American English. All children were five years old [age range from 5;0 to 5;11], developing typically according to parental reports and a pure-tone hearing screen. All adults were University of Oregon undergraduate students with self-reported normal hearing and language.

2.2. Materials

Productions of lexical stress patterns by children and adults were compared in two- and three-syllable words. Table 1 shows five examples of the examined stress patterns: trochees (SW) and iambs (WS) in two-syllable words; dactyls (SWW), amphibrachs (WSW), and anapests (WWS) in three-syllable words. Four words were selected to represent each of the patterns yielding 20 target words in total.

2.3. Procedure

The participants produced each target word in three prosodic environments – in isolation, in utterance-initial and utterance-final positions (Table 1). They were asked to say each word in its plural form when possible in order to avoid preceding articles, which would have increased the number of syllables in productions (i.e., two-syllable *donkeys* rather than three-syllable *a donkey*).

First, a tester showed the picture of a target word prompting a speaker with "These are …" sentence. After the word was elicited in isolation, the speaker was asked to make a sentence starting with the target word, and another sentence starting with

Mister Potato Head (*MPH* in Table 1 examples) and ending with the target word. If the word was produced in the utterance-medial position, then the speaker was asked to create another sentence.

Table 1. *Variation in stress pattern (S=strong, W=weak) and phrasal position of the stimuli.*

Stress	Isolation	Utterance initial	Utterance final
SW	*Donkeys*	*Donkeys are farm animals*	*MPH has pet donkeys*
WS	*Afraid*	*Afraid means scared*	*MPH is afraid*
SWW	*Pelicans*	*Pelicans are smart*	*MPH likes pelicans*
WSW	*Tomatoes*	*Tomatoes are red*	*MPH can cut tomatoes*
WWS	*Kangaroos*	*Kangaroos jump*	*MPH pet kangaroos*

2.4. Analysis

A total of 1,380 word productions were analyzed (5 stress patterns x 4 words x 3 positions x 23 speakers). Disfluent words, utterance-initial words followed by a pause, utterance-final words preceded by a pause, and words that speakers failed to produce in a required prosodic position were excluded from further analysis. Duration and rms amplitude were measured in the sonorant rhymes of remaining words (children: 1374 rhymes; adults: 1693 rhymes).

To compare child and adult productions of words varying in their lexical stress patterns, five separate mixed-effects model analyses were conducted for each acoustic correlate. In these models, group, prosodic position and rhyme were fixed factors; word and speaker were random factors. The following effects were expected to be significant: The effect of group due to the higher speech rate in adults than children; the effect of prosodic position due to the boundary-related lengthening and domain-initial strengthening [5, 8]; and the effect of rhyme due to the longer duration of lexically stressed than unstressed syllables [1, 2, 3, 4]. Significant interactions between group and the other fixed factors were of a particular interest in this study.

3. Results

Results are reported below by stress pattern. As expected, the main effects of group and rhyme were significant in all analyses; they are not discussed for each stress pattern below in the presence of significant interactions. However, position was a significant predictor in models of rhyme amplitude, but not duration. Therefore, the amplitude data is shown by position in Figures 2-3, 5-7, whereas the duration data is collapsed across positions in Figures 1 and 4.

3.1. Two-syllable words

To summarize the results detailed below, children differed from adults mostly in their production of duration patterns in the iambic words, and in their production of amplitude patterns in the utterance-final words. Children lengthened the stressed syllable in iambs more than adults did. Taken together, the results suggest that by the age of five children have learned to maintain duration patterns associated with lexical stress across different prosodic positions, but amplitude patterns associated with lexical stress and the prosodic position of a word are slower to develop.

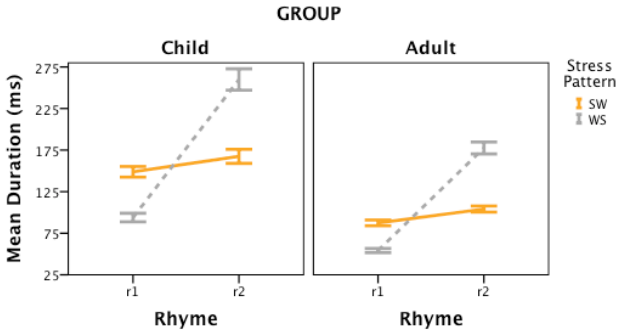

Figure 1: *Duration patterns in two-syllable trochees (SW, solid lines) and iambs (WS, dashed lines).*

3.1.1. Trochees (SW)

The mixed-effects analysis on duration measurements showed significant effects of group [$F(1, 21.20) = 37.26$, $p < .001$], and rhyme [$F(1, 449.04) = 12.93$, $p < .001$]. Figure 1 (solid lines) illustrates that children have longer rhyme durations than adults, most likely due to a slower speech rate. Averaged across the two groups, the unstressed rhyme (*r2*) was 18 ms longer than the stressed rhyme (*r1*), even though a reverse relationship was expected in the strong-weak stress pattern. This finding may be attributed to the final lengthening in utterance-final and isolated words, and to the long sonorant rhymes in unstressed syllables of selected trochaic words (e.g., *donkey, peacock, helmet*).

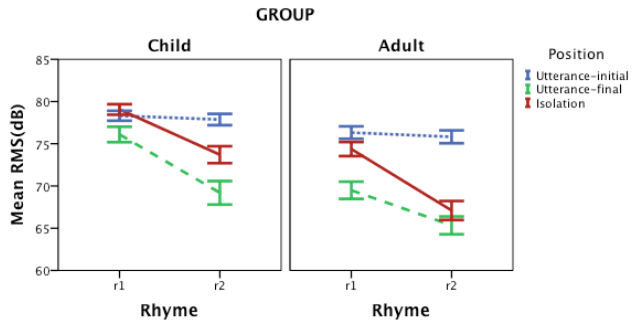

Figure 2: *Amplitude patterns in trochees (SW) in the utterance-initial position (dotted lines), utterance-final position (dashed lines), and isolation (solid lines).*

The analysis of amplitude showed significant effects of group [$F(1, 21.25) = 7.56$, $p = .012$], rhyme [$F(1, 450.26) = 100.55$, $p < .001$], position [$F(2, 451.83) = 90.22$, $p < .001$], and significant interactions between group and position [$F(2, 451.66) = 6.85$, $p = .001$], and between rhyme and position [$F(2, 450.26) = 20.60$, $p < .001$]. Figure 2 illustrates that the difference in amplitude between rhymes is larger for words produced in isolation and in utterance-final position than in utterance-initial words. Also, the difference in the amplitude between the utterance-initial and utterance-final words is larger in adults than in children. Furthermore, in adult productions, isolated words

start with a similar amplitude as utterance-initial words, and end with a similar amplitude as utterance-final words. In children this tendency is less pronounced. Lastly, comparing the two groups by prosodic position, the amplitude patterns of utterance-initial words are the most similar.

3.1.2. Iambs (WS)

The analysis of rhyme durations in words with the weak-strong stress pattern showed significant effects of group [$F(1, 19.46) = 41.09$, $p < .001$], rhyme [$F(1, 395.18) = 428.93$, $p < .001$], and the interaction between these two factors [$F(1, 395.15) = 7.78$, $p < .006$]. Figure 1 (dashed lines) suggests that the durational difference between the first and the second rhymes is larger in children than in adults. Children appear to lengthen the lexically stressed syllable (i.e., *r2*) more than adults do in the words *afraid, baloons, guitar,* and *construct*.

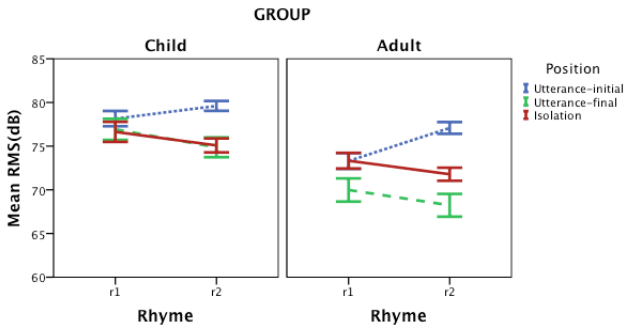

Figure 3: *Amplitude patterns in iambs (WS) in the utterance-initial position (dotted lines), utterance-final position (dashed lines), and isolation (solid lines).*

The analysis of amplitude showed significant effects of group [$F(1, 21.45) = 10.41$, $p = .004$], position [$F(2, 410.35) = 35.76$, $p < .001$], as well as the interactions between group and position [$F(2, 408.80) = 11.82$, $p < .001$] and between rhyme and position [$F(4, 407.17) = 12.49$, $p < .001$]. Figure 3 illustrates that the amplitude patterns of words produced in the two phrasal positions (dotted and dashed lines) are more different from each other in adults than children.

3.2. Three-syllable words

To summarize the findings detailed below, both children and adults differentiated lexical stress patterns in three-syllable words in terms of the durational correlate of stress. They lengthened stressed syllables more than adjacent unstressed syllables to a similar degree in all three prosodic environments (i.e., *r1* > *r2* in SWW; *r1* < *r2* > *r3* in WSW; and *r2* < *r3* in WWS stress patterns). However, children differed from adults with regard to the amplitude patterns of three-syllable words. In particular, they produced isolated and utterance-final amplitude patterns in a similar fashion, whereas adults clearly distinguished between them.

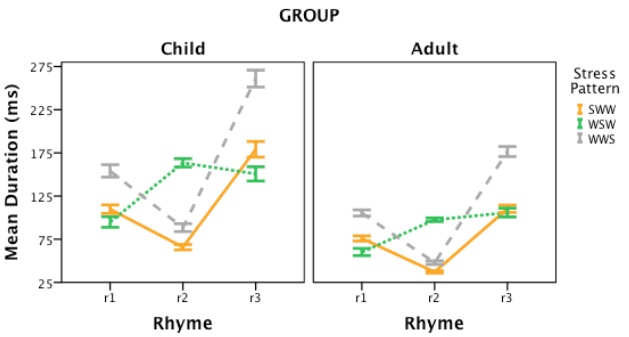

Figure 4: *Duration patterns in three-syllable dactyls (SWW, solid lines), amphibrachs (WSW, dotted lines) and anapests (WWS, dashed lines).*

3.2.1. Dactyls (SWW)

The mixed-effects analysis of rhyme durations in dactyls showed significant effects of group [$F(1, 17.39) = 49.53$, $p < .001$], rhyme [$F(2, 688.79) = 229.90$, $p < .001$], and the interaction between these two factors [$F(2, 688.79) = 12.73$, $p < .001$]. Figure 4 (solid lines) illustrates that the durational difference between the stressed (*r1*) and the adjacent unstressed (*r2*) rhymes is larger in children than in adults. The final syllable rhyme (*r3*), which is the most distant from the lexically stressed syllable, is also relatively longer in children than adults.

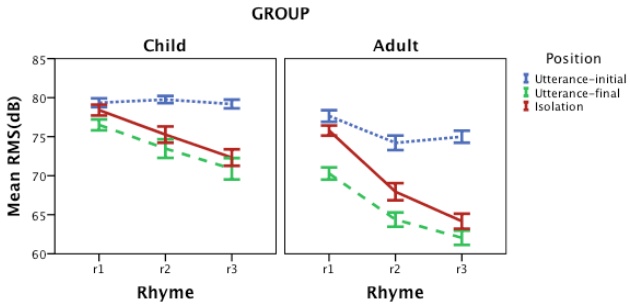

Figure 5: *Amplitude patterns in dactyls (SWW) in the utterance-initial position (dotted lines), utterance-final position (dashed lines), and isolation (solid lines).*

In the analysis of rhyme amplitude all main effects and two-way interactions were significant: group [$F(1, 20.98) = 16.50$, $p = .001$]; position [$F(2, 696.66) = 150.26$, $p < .001$]; rhyme [$F(2, 692.97) = 90.00$, $p < .001$]; group x position [$F(2, 695.96) = 12.29$, $p < .001$]; group x rhyme [$F(2, 692.97) = 11.96$, $p < .001$], and rhyme x position [$F(4, 692.97) = 13.54$, $p < .001$]. Figure 5 illustrates that the amplitude decreased across isolated and utterance-final words but not much across utterance-initial words. The rhyme amplitude varied as a function of the prosodic position and the rhyme position more in adults than in children. The amplitude patterns in SWW words were similar to the patterns in SW words (Figures 2 and 5).

3.2.2. Amphibrachs (WSW)

The analysis of rhyme durations in amphibrachs yielded the following significant results: group [$F(1, 20.06) = 45.81$, $p < .001$]; rhyme [$F(2, 678.78) = 83.07$, $p < .001$]; and group x rhyme [$F(2, 678.78) = 6.26$, $p = .002$]. Figure 4 (dotted lines) shows that the stressed rhyme (*r2*) is longer than the adjacent unstressed rhymes, more so in children than adults.

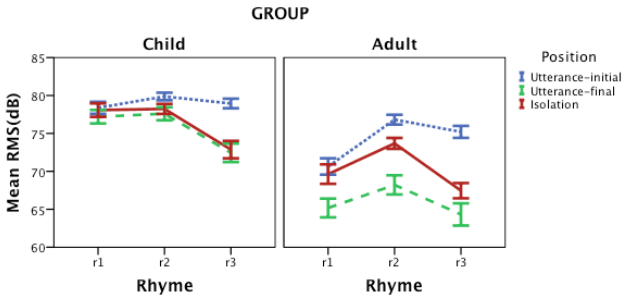

Figure 6: *Amplitude patterns in amphibrachs (WSW) in the utterance-initial position (dotted lines), utterance-final position (dashed lines), and isolation (solid lines).*

The analysis of rhyme amplitude yielded the following significant results: group [$F(1, 21.18) = 16.35$, $p = .001$]; position [$F(2, 683.04) = 70.72$, $p < .001$]; rhyme [$F(2, 681.15) = 37.79$, $p < .001$]; group x position [$F(2, 682.98) = 15.13$, $p < .001$]; group x rhyme [$F(2, 681.15) = 10.93$, $p < .001$]; and rhyme x position [$F(4, 681.15) = 10.38$, $p < .001$]. Figure 6 illustrates that the stressed syllable (*r2*) has higher amplitude than the adjacent syllables (*r1* and *r3*) in adults' productions. In children's productions, the amplitude of the stressed and the preceding unstressed syllables do not differ from each other. In both groups the final rhyme amplitude was lower than in the preceding rhyme.

3.2.3. Anapests (WWS)

The analysis of rhyme durations in anapests yielded similar results to other three-syllable words: group [$F(1, 21.57) = 44.50$, $p < .001$]; rhyme [$F(2, 637.10) = 379.85$, $p < .001$]; group x rhyme [$F(2, 637.10) = 8.57$, $p < .001$]. Figure 4 (dashed lines) shows that relative to the adjacent unstressed rhyme (*r2*), children lengthened the lexically stressed rhyme (*r3*) more than adults did. The WWS and SWW patterns look alike but the unstressed middle rhyme is more shortened relative to the adjacent rhymes in the WWS type than in the SWW type.

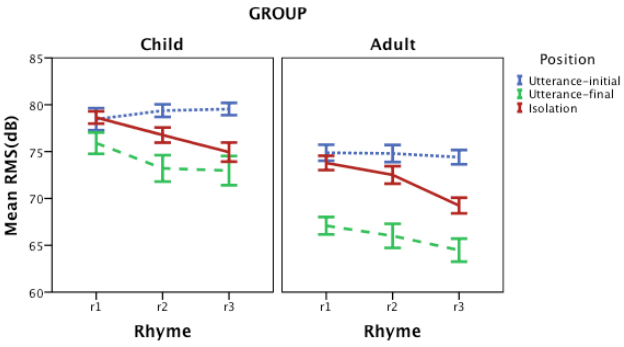

Figure 7: *Amplitude patterns in anapests (WWS) in the utterance-initial position (dotted lines), utterance-final position (dashed lines), and isolation (solid lines).*

The analysis of amplitude yielded the following results: group [$F(1, 21.19) = 12.91$, $p = .002$]; position [$F(2, 640.85) = 75.79$, $p < .001$]; rhyme [$F(2, 638.13) = 13.97$, $p < .001$]; group x position [$F(2, 639.70) = 9.50$, $p < .001$]; and rhyme x position [$F(4, 638.12) = 5.95$, $p < .001$]. Similar to the interpretation of Figure 5, Figure 7 suggests that amplitude decreased across isolated and utterance-final words, but not utterance-initial words. The amplitude pattern of utterance-final words varied more from the other prosodic position in adults than in children.

4. Discussion

Children's and adults' productions of five lexical stress patterns in three prosodic positions were investigated in this study. Two acoustic correlates of lexical stress were examined: duration and amplitude of sonorant rhymes in the target words. Surprisingly, the boundary-related prosodic position had no influence on production of duration patterns. An interaction between prosodic position and the type of the rhyme was expected such as the lengthening of lexically stressed rhymes and word-final rhymes when the word was produced in the utterance-final position [5]. This interaction was not observed in either bi- or tri-syllabic words. This boundary-related rhyme lengthening might have been obscured by the choice of the target words (e.g., trochaic words with long sonorant rhymes in unstressed syllables).

As for the amplitude correlate of stress, the amplitude patterns of adults in each word type varied as a function of prosodic position, whereas children tended to have similar amplitude patterns in words produced in isolation and in utterance-final position. Furthermore, children produced tri-syllabic words of all lexical types with similar amplitude patterns in the utterance-initial position.

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