Tonal Alignment and Segmental Timing in English-Speaking Children*

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Tonal alignment has been shown to be sensitive to segmental timing. This suggests that development of the former may be influenced by the latter. The developmental literature reports that English-speaking children do not attain adult-like competence in segmental timing until after age 6. While this suggests that the ability for alignment may be mastered after this age, this possibility is speculative due to paucity of data. Accordingly, the present study sought to determine whether 7- and 8-year old English-speaking children exhibit adult-like alignment and segmental timing in their speech. Seven children (ages 7 and 8) and 10 adults (ages 19 to 24) repeated pre-recorded sentences. Their productions were analyzed acoustically. The children showed adult-like performance on three out of four measures of alignment. They performed comparably with adults on all measures of segmental timing. These results suggest that the English-speaking children's ability for alignment may reach adult levels after mastery of segmental timing.

Keywords: intonation, tonal alignment, phonology, phonetics, language acquisition

1 Introduction

Intonation refers to pitch variations in spoken language that extend over entire utterances such as sentences and phrases (Ladd 2008). It is made up of subsystems known as tones (Cruttenden 1997), which are targeted by speakers (Gussenhoven 1984, Ladd 2008). The most prominent tone in a phrase, often the last one, is called nuclear tone. All other tones preceding the nuclear are called prenuclear tones. Tones are timed to occur with specific portions of the segmental string (Beckman & Pierrehumbert 1986, Silvermann & Pierrehumbert 1990). This phenomenon is known as alignment.

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Data on the development of alignment in English-speaking children are limited. It has been shown that children acquire most tones before they reach the two-word combination stage around age 2 (See Snow & Balog 2002 for a review). However, it is unclear whether ability for alignment develops at the same time. A recent study suggests that English-speaking children may master ability for alignment late (Astruc et al. 2013). Astruc and colleagues investigated the alignment of nuclear tones in the speech of 2-, 4- and 6- year old Spanish-, Catalan- and English-speaking children. They found that Catalan- and Spanish-speaking children were more precise at aligning tones compared to English-speaking children. They suggested that the difference in performance may have been due to immature ability for segmental timing.

Studies on adults have shown that alignment is sensitive to segmental timing (Schepman, Lickley & Ladd, 2006, Silverman & Pierrehumbert 1990). For example, Silverman and Pierrehumbert (1990) found that the alignment of F0 peaks on pitch-accented words in English is affected by vowel duration. The developmental literature also suggests that mastery of segmental timing may occur after age 6. For instance, Grabe et al. (1999) examined variability in vocalic duration in the speech of 4-year old French and English-speaking children and found that only the French-speaking children had acquired adult-like relative duration of final syllables. Similarly, Payne et al. (2012) investigated final-syllable lengthening and found that 2- to 6-year old English-speaking participants produced excessively long final syllables, compared to adults.
Taken together, these findings suggest that the ability for alignment may reach adult levels after age 6 and that ability for alignment and segmental timing may develop together. The present study investigates these possibilities by examining alignment and segmental timing in the speech of 7- and 8-year old English-speaking children. We ask the following research questions:

(1) Do 7- and 8-year old English-speaking children exhibit adult-like ability for alignment? If the answer to this question is yes, then we would expect our participants to perform comparably with adult controls on all measures of alignment. On the other hand, if the answer to this question is negative, then we would expect a significant difference between the performance of children and adults on measures of alignment.

(2) Does ability for alignment develop together with ability for segmental timing in these children? If yes, we would expect children to perform similarly on measures of alignment and segmental timing. If the answer to this question is no, then we would expect children to perform differentially on measures of alignment and segmental timing.

2 Method

2.1 Participants

Seven children (four 7- and three 8-year olds) and 10 adults aged 19-24 participated in the study. All subjects were monolingual speakers of American-English residing in Grand Forks, North Dakota. Participants were from predominantly middle-class homes. They passed a pure-tone audiometric screening (30dB HL at 1000, 2000 and 4000Hz) administered according to the American Speech-Language and Hearing Association (2005) guidelines. The children were recruited through an advertisement placed in the Grand Forks public schools newsletter. They

were included in the study if they had typical speech and language as determined by the Goldman-Fristoe Test of Articulation-Second Edition (GFTA-2, Goldman & Fristoe 2000) and the Clinical Evaluation of Language Fundamentals–Fifth Edition (CELF-5, Wiig et al. 2013). Adult participants were undergraduate students. Their speech was screened using "The Rainbow" passage (Fairbanks 1960).

2.2 Stimuli

Stimuli comprised of 20 declarative sentences. There were 5 practice and 15 test sentences (See Appendix for list of stimuli). The sentences were 4 to 6 syllables long (e.g., a *dog* rode in the van). For measures of alignment, we selected words with which the first prenuclear tone in each sentence was associated (e.g., *dog* in the preceding example). To ensure relatively smooth and reliably extracted F0 contours, target words were composed of only voiced sounds.

2.3 Procedure

Participants were tested in a quiet room. Hearing screenings were conducted with a portable Maico audiometer (MA 30) prior to administration of the stimuli. The stimuli were played to participants via a set of Dell stereo loud speakers connected to a desktop computer. Stimuli were presented at listening levels comfortable for the participants. The participants were asked to listen to the lady on the computer and repeat exactly what she says. The practice stimuli were played first. The test sentences were administered after participants understood the task. During the administration, sentences were played back if children indicated difficulty hearing or understanding the sentences. If participants made any errors in repeating stimuli, they were prompted by the researcher to repeat exactly what they heard. Repeated productions were recorded onto an Olympus LS-100 digital audio-recorder.

2.4 Recording and Measurements

The recordings were analyzed using Praat (Boersma & Weenink 2004). Each target word was segmented manually as follows: syllable onset, vowel onset, vowel offset and syllable offset. Peaks and valleys of the prenuclear tone associated with target words were also located and labeled as P and V, respectively.

Adult data have shown that peaks and valleys are aligned with the onset or offset of syllables and vowels (Arvaniti et al. 1998, Xu 1998, Ladd et al. 1999, Atterer & Ladd 2004, Ladd et al. 2009). This has been found for both nuclear (e.g., Prieto et al. 1995) and prenuclear tones (e.g., Silverman & Pierrehumbert 1990, Arvaniti et al. 1998, Atterer & Ladd 2004). Thus, following previous studies (e.g., Ladd et al. 2000, Astruc et al. 2013), we measured the alignment of valleys relative to the onset of the vowel in the target word and the onset of the target word, and the peak relative to the offset of the stressed vowel and syllable. We calculated valley alignment by subtracting the temporal location of the (1) syllable onset from the location of the valley, (2) vowel onset from location of the vowel. Peak alignment was measured as (1) the temporal location of the syllable offset minus the location of the peak (2) location of the vowel offset

minus the location of the peak. Segmental measures included the durations of the target word, the vowel in the target word, the final word and the entire sentence.

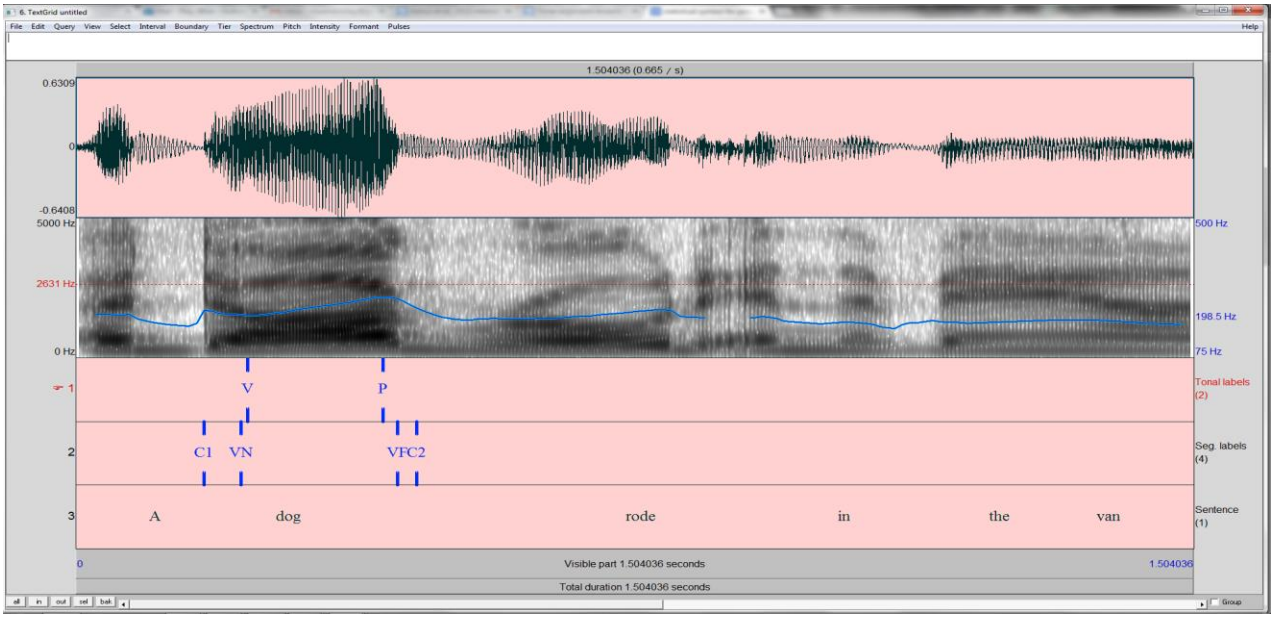

Figure 1: Waveform (first upper panel) and spectrogram showing F0 contour (second upper panel) of the utterance "A dog rode in the van". On the row marked as tonal labels, V and P indicate the valley and peak respectively; on the row marked as segmental labels, C1 shows syllable onset, VN = vowel onset, VF = vowel offset and C2 = syllable offset.

3 Results

A one-way analysis of variance (ANOVA) was conducted to compare the performance of the two groups. The independent variable was participants' group (children, adults). There were 8 dependent variables: alignment of valley with syllable onset, alignment of valley with vowel onset, alignment of peak with syllable offset, alignment of peaks with vowel offset, durations of vowels, target words, final words and sentences. Each variable contained 255 tokens (i.e. 17 subjects x 15 sentences). Alpha was set at 0.05.

There was no significant difference between the two groups on alignment of valleys with the onset of syllables [$F(1, 253) = 0.008$, $p = 0.930$] and onset of vowels [$F(1, 253) = 0.442$, $p = 0.507$]. Alignment of peaks with vowel offset was also not significant [$F(1, 253) = 0.002$, $p = 0.967$]. However, there was a significant difference between the groups on the alignment of peaks with syllable offset [$F(1, 253) = 10.798$, $p = 0.001$].

For segmental timing measures, both groups performed comparably on vowel [$F(1, 253) = 0.033$, $p = 0.856$], target word [$F(1, 253) = 2.41$, $p = 0.121$] and final word [$F(1,253) = 0.00009$, $p = 0.993$] durations. However, sentences were significantly longer for children (1520.57ms) compared to adults (1374.07ms) [$F(1, 253) = 28.03$, $p < 0.001$].

4 Discussion

The present study sought to determine whether 7- and 8-year old English-speaking children exhibit adult-like ability for tonal alignment and segmental timing. We found that the children performed comparably with adults on all measures of alignment except on alignment of peaks with syllable offset. While the reason for the differential performance on peak alignment is not entirely clear, a possible explanation may be children's inability to manage tonal crowding (Astruc et al. 2013). All target words in the current study were monosyllabic and oxytones (words with stress on the last syllable). This required children to fit both valleys and peaks onto one syllable which may have led to the early alignment of peaks relative to syllable offset. Astruc et al. (2013) found similar results in the alignment of peaks with syllable offset. In their study, 2-year old Spanish- and Catalan-speaking children showed early alignment of peaks relative to syllable offset on oxytones. However, these children's alignment of high tones in paroxytone (words with the stress on the penultimate syllable) and proparoxytones (words with stress on the antepenultimate syllable) were adult-like. It is unclear whether our participants would have shown adult-like alignment on words with different stress patterns. However, our study shows that the ability for alignment is not entirely adult-like by age 8.

It is interesting that the imprecise timing of peaks with syllable offset did not affect valley alignment. This finding corroborates claims that valleys and peaks may be independently aligned (Arvaniti et al. 1998, Silverman & Pierrehumbert 1990). This also suggests that phonetic ability for alignment of valleys may develop and stabilize earlier than peaks. Previous studies have shown that tonal direction is also acquired in a specific order. For example, acquisition of falling tones occurs before age two (e.g., Snow 2002) whereas rising tones are not mastered even by age 4 (Snow 1998). These indicate that components of intonation may be acquired individually.

On measures of segmental timing, children performed comparably with adults. There was no difference between the groups on measures of target word, final syllable and vowel (in the target word) durations. These durations were purely based on segments unlike sentence durations that may be influenced by inter-word pauses. Thus, although sentence durations were significantly longer for children than adults, it may have been as a result of longer pauses in the speech of the children.

Taken together, participants in our study had adult-like segmental timing but alignment was not completely adult-like. This suggests that ability for alignment may develop together with or after mastery of segmental timing. However, due to the limited number of participants in the present study, results must be interpreted cautiously. A study involving a larger sample with a cross-section of ages is warranted to trace the development of segmental and prosodic timing.

Appendix

Practice stimuli

a. The man won the game.
b. The dog has a bone.
c. My mom made my bed.
d. My mom loves gum.
e. The girl has a doll.

Test Stimuli

1. The men won the game.
2. The man bagged the apple.
3. The man named the dog.
4. My mom loved jelly.
5. The dog barked at me.
6. The man made the doll.
7. My dad nailed the wood.
8. My gown is in the rain.
9. My ring is red.
10. The man did the limbo.
11. My mom made a mug.
12. My dad red to me.
13. My bag is in the draw.
14. My doll is in my bag.
15. The bird ate my bread.

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