Issues in East Asian Language Acquisition

Edited by Minehru Nakayama

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Phonetic Parameters of 
Tone Acquisition in Taiwanese*

Jane Tsay

0. Introduction
One of the fundamental issues in phonological acquisition concerns how children acquire phonological categories. In the generative convention, it has been assumed that a phonological category is defined by phonological features which usually are motivated by systemic-internal evidence like distribution and alternation (e.g., Chomsky & Halle, 1968). This kind of representation might be useful in describing the sound system of a language, but whether it is the real target for children acquiring the language is open to debate. In this paper, we argue that during the process of acquisition children treat phonological categories as phonetic wholes rather than as sets of phonological features. In particular, we show how study of an important, but commonly neglected phonetic parameter, i.e. duration, provides evidence in support of the claim that tone categories are phonetic (gestural) wholes rather than abstract pitch features for young children.

Before a child acquires the sound system of a language, the speech input for her is just a set of gradient surface phonetic forms with great variation and redundancy. The child does not necessarily know which aspects of the speech signal are distinctive, which are redundant, and which are irrelevant and should be ignored. It makes sense then to consider the possibility that at an early stage, a phonological category might just be a phonetic target that the child is trying to hit using whatever is available in the acoustic signal, i.e. a consolidation of phonetic parameters, not just one.

Following this line of reasoning, acquiring phonological categories at first means acquiring all phonetic details that are perceivable by children. Therefore, we expect the child to master all contrasts between phonological categories not only using one phonetic parameters, but also with parameters that are redundant in the adult system. Taking
lexical tone as an example, pitch is apparently the core phonetic parameter used by adults to contrast tone categories (e.g., Waug, 1967; Gandour, 1978; Maddieson, 1978a), while duration contrasts, though systematic, are redundant (Zee, 1978; Lin, 1988; Tseng, 1990). We predict that when a child has reached a stage when she can master the pitch dimension of tonal contrasts, she should also be making similar duration contrasts among different tones found in adult speech. In this paper, we will show this is exactly what happens in tone acquisition in Taiwanese.

Given that the child is acquiring an entire phonetic gesture rather than just core features, we should also find cases where so-called redundant parameters are actually mastered before the core features. This seems to be the case for children acquiring a subset of the Taiwanese tone system, as we will show below.

However, since these phonetic wholes are learned, prototypical characterizations of phonological contrasts, they are not the same as purely physiological implementations of the gestures. The child is still acquiring abstract categories. Therefore, we predict that phonetic variation caused by changing from one phonological category to another in accordance with the adult phonology (e.g., from closed syllable to open syllable) will result in a categorical duration change.

Using data from both phonetic transcription and acoustic analysis, we provide evidence for the above claims. Before doing that, we first describe the background and methodology of the study.

1. Background
1.1. Theoretical Background
The idea of phonological categories being phonetic wholes is not new. In particular, the theory of articulatory phonology (Browman & Goldstein, 1986, 1992) claims that the basic units of phonological contrast in adult speech are articulatory gestures. These gestures ‘are also abstract characterizations of articulatory events, each with an intrinsic time or duration’ (Browman & Goldstein, 1992: 155). This approach is consistent with studies of phonological development that find that in an earlier stage, children seem to store and retrieve words as holistic patterns of articulatory routines rather than phonemes (Fry, 1966; Ferguson & Farwell, 1975; Locke, 1983; Studdert-Kennedy, 1987; Vihman, 1994).

In the domain of lexical tone, tone features proposed in the linguistic literature have been associated primarily with one dimension, i.e., fundamental frequency (in its perception or its production) (Wang, 1967; Woo, 1969; Halle & Stevens, 1971; Yip, 1980; Bao, 1990; Duanmu, 1990; Tsay, 1994). Duration is not considered a core phonetic parameter for representing tonal contrasts, regardless of the systematic correlation between duration and fundamental frequency (Lehiste, 1970; Ohala & Ewan, 1972; Sandberg, 1973; Zee, 1978; Lin, 1988; Tseng, 1990).

Therefore, if we assume, following articulatory phonology, that phonological contrast is made by gestural wholes, we would expect that children also make distinctions in duration, in addition to fundamental frequency, when contrasting tone categories. Our evidence comes from tone acquisition data in Taiwanese.

1.2. Syllable Structure and Tonal System in Taiwanese
Taiwanese is a dialect of Southern Min (or Minnan) Chinese spoken in Taiwan. Morphemes in Taiwanese are overwhelmingly monosyllabic, as in other Sinic languages. We first introduce the syllabic structure of Taiwanese because it is crucial for our understanding of the tonal system of the language.

As shown below, only the nucleus vowel is obligatory in a syllable. The nucleus vowel can be preceded by a consonant and/or a high vowel (which can be treated as a prevocalic glide). There can only be one segment following the nucleus vowel. It is either a high vowel (i.e. prevocalic glide) or a consonant. The choice of codas consonant is very restricted. It can only be a nasal (m, n, ng), or a stop (p, t, k, or glottal stop q). Syllables ending with a stop are called checked syllables in the literature.

(1) Taiwanese Syllable Structure
(C)G(O)V(G or C)

Most monosyllabic morphemes in Taiwanese, except for some function words, carry a lexical tone. There are seven lexical tones in Taiwanese including two Rusheng (also called Entering, A abrupt, or short tones) and five non-Rusheng (or long tones). Rusheng only occurs in checked syllables, while non-Rusheng occurs in all other syllables, i.e., those ending with a sonorant (vowel, glide, nasal). In addition to the syllabic constraint, Rusheng tones are distinct from non-
that most studies on tone acquisition in Siinic languages focus on the acquisition of the tone system and the non-Rusheng order of tones in the language (e.g., for Mandarin, see Chao, 1951; Chuimei, 1977, 1978; Li & Thompson, 1977, 1978; Li, 1978; Su, 1985; for Cantonese, see Tse, 1978; So & Dodd, 1995; for Taiwanese, see King, 1980; Tsu, 1989).

Based on the above studies, consensus has been reached about some aspects of tone acquisition in Siinic languages. For example, tones are acquired much faster and are mastered much earlier than segments. Roughly speaking, by the age of two children have mastered all the tone system and are making very few mistakes. By contrast, segment acquisition at this stage still has a low accuracy rate (Tse, 1978; Li & Thompson, 1978). One phenomenon related to the poor mastery of segments at the earlier stage is coda dropping. This will be relevant to our discussion of the acquisition of Rusheng later.

When judging the accuracy of children's productions of tone, all the studies focus solely on the pitch of the tones, including pitch height (high, mid, low) and shape (falling, rising). However, there is another important aspect of tone that has been neglected, namely, the duration of the syllable that carries the tone.

1.4. The Role of Prosody in Perceptual Development

Duration is a phonetic parameter that is often neglected by the literature on tone acquisition for an understandable reason, namely, it is a redundant parameter for tone. However, it has long been recognized that inasts are very sensitive to prosodic cues (such as intonation, stress, duration) from a very early age (DeCasper & Fifer, 1980; Fernald, 1984; Jusczyk & Thompson, 1978; Mohler et al., 1988). Also, infants appear to be able to use suprasegmental cues to locate the boundaries of prosodic constituents, in particular, prosodic markers of syntactic units such as clauses and phrases (see Jusczyk (1997) for a detailed review). Therefore, the prosodic bootstrapping hypothesis has been proposed to account for children's acquisition of grammar (Gleitman & Wanner, 1982; Peters, 1983; Morgan, 1986; Morgan & Demuth, 1996; Tsay, 1999). More specifically, the bootstrapping hypothesis claims that the child uses suprasegmental information (e.g., stress, pitch contour, and vowel lengthening) to infer something about syntactic structure. Prosodic constituents like intonational phrases, or tone groups in the case of Taiwanese tone sandhi, though not identical

1.3. Tone Acquisition in East Asian Languages

It has been recognized that East Asian tone languages are typologically different from African tone languages (Odden, 1995; Yip, 1995). As pointed out by Yip (1995) the rich tone inventory is a primary way in which Asian tone languages differ from African tone languages. Moreover, tone in Asian tone languages seems to play a strong lexical (paradigmatic) function, unlike African tonal systems which are usually more syntagmatic and involve more non-local alternations (Odden, 1995). Since tone plays a crucial role in lexical distinctions in Siinic languages, we expect that the acquisition of the tone inventory is one of the first challenges for young children. Therefore, it is not surprising

<table>
<thead>
<tr>
<th>Non-Rusheng</th>
<th>Terms in this paper</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yin Ping</td>
<td>High</td>
<td>high level</td>
<td>si55 'poem'</td>
</tr>
<tr>
<td>Yang Ping</td>
<td>Rising</td>
<td>low rising</td>
<td>si13 'time'</td>
</tr>
<tr>
<td>Shang</td>
<td>Falling</td>
<td>high falling</td>
<td>si53 'death'</td>
</tr>
<tr>
<td>Yin Qu</td>
<td>Low</td>
<td>low (falling)</td>
<td>si11 'door'</td>
</tr>
<tr>
<td>Yang Qu</td>
<td>Mid</td>
<td>mid level</td>
<td>si33 'temple'</td>
</tr>
</tbody>
</table>

Rusheng

| Yin Ru   | Yin Ru | low abrupt | si53 'color' |
| Yang Ru  | Yang Ru | high abrupt| si53 'ripe' |

that Rusheng tones are also called short or short-range tones.

The tone inventory of the Chiuai dialect of Taiwanese discussed in this paper is given in Table 1 below, with the traditional labeling of tones in the first column and the terms used in this paper in the second column. Tone values are given in five-point scale tone letters (Chao, 1930), with 5 denoting the highest pitch and 1 the lowest. The tone values given in Table 1 are for words/morphemes in isolation or in so-called juncture position, i.e. at the end of a tone group (a prosodic phrase which is syntactically defined, see Chen, 1987; Lin, 1994). All seven tones show up with a different "sandhi" tone value when followed by another tone in a tone group. Since it is beyond the scope of our discussion, we do not include the sandhi tone values in the above tone inventory.

Table 1. Taiwanese Tone Inventory

Rusheng tones in being shorter in duration. This is why Rusheng tones are also called short or short-range tones.

The tone inventory of the Chiuai dialect of Taiwanese discussed in this paper is given in Table 1 below, with the traditional labeling of tones in the first column and the terms used in this paper in the second column. Tone values are given in five-point scale tone letters (Chao, 1930), with 5 denoting the highest pitch and 1 the lowest. The tone values given in Table 1 are for words/morphemes in isolation or in so-called juncture position, i.e. at the end of a tone group (a prosodic phrase which is syntactically defined, see Chen, 1987; Lin, 1994). All seven tones show up with a different "sandhi" tone value when followed by another tone in a tone group. Since it is beyond the scope of our discussion, we do not include the sandhi tone values in the above tone inventory.

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<tbody>
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<td>High</td>
<td>high level</td>
<td>si55 'poem'</td>
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<tr>
<td>Yang Ping</td>
<td>Rising</td>
<td>low rising</td>
<td>si13 'time'</td>
</tr>
<tr>
<td>Shang</td>
<td>Falling</td>
<td>high falling</td>
<td>si53 'death'</td>
</tr>
<tr>
<td>Yin Qu</td>
<td>Low</td>
<td>low (falling)</td>
<td>si11 'door'</td>
</tr>
<tr>
<td>Yang Qu</td>
<td>Mid</td>
<td>mid level</td>
<td>si33 'temple'</td>
</tr>
</tbody>
</table>

Rusheng

| Yin Ru   | Yin Ru | low abrupt | si53 'color' |
| Yang Ru  | Yang Ru | high abrupt| si53 'ripe' |
to syntactic constituents, are predictable from syntactic structure (Selkirk, 1984, 1985; Nespor & Vogel, 1986). Since young children seem to be very sensitive to prosodic cues like duration, the duration parameter in tonal contrasts should be perceivable for them. The gestural approach to phonological categories thus predicts that children will incorporate duration into their tonal gestures quite early.

2. Method

Previous studies of Taiwanese tone acquisition have found that non-Rusheng tones are mastered earlier than Rusheng tones (King, 1980; Hsu, 1989). More specifically, King reports that by 2;5 the child he studied had already mastered all five non-Rusheng tones, whereas the two Rusheng tones were not mastered until about 2;8. Hsu reports only one Rusheng (You Ru) which the child she studied acquired at 1;11. The other Rusheng (Yang Ru) had been neutralized with a non-Rusheng tone Yang Ou (the Mid tone) in the child’s dialect. Following standard methods in acquisition research, these studies judge the accuracy of tones by comparing the pitch contour of each tone with that of adults, using impressionistic transcription by linguists. In other words, the accuracy was judged based mainly on the pitch parameter of tone. Neither of the studies reports observations in another phonetic parameter of tone, i.e. duration.

This study uses two kinds of methodologies: one involves the traditional impressionistic transcription of the child’s speech for accuracy of all the tones being acquired, and the other involves acoustic measurements of syllables with different tones.

2.1. Speech Data Collection and Transcription

The child under examination is a boy (Xuan) from a Taiwanese speaking family living in a small town in Chiayi County, southern Taiwan. recordings of the child at play were made through home visits once every one to two weeks. Digital mini-recorders were used for recording. There were a total of 10 recordings (670 minutes) during the period when the child was between 2;1.7 and 2;5.4. The MLU (by syllable) was 3.1 during the period of 2;1-2;3 and 3.71 during the period of 2;3-2;5.

The recordings were first transcribed by one linguist, usually the recorder/observer, and then double-checked by another two linguists.
Phonetic Parameters of Tone Acquisition in Taiwanese shown in Table 3 below, the relative duration of the H tone in Taiwanese is longer than that in Mandarin, and the Falling tone is shorter.

<table>
<thead>
<tr>
<th></th>
<th>Rising</th>
<th>High</th>
<th>Mid</th>
<th>Falling</th>
<th>Low</th>
<th>Yang</th>
<th>Ru</th>
<th>Yin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lin</td>
<td>146</td>
<td>143.3</td>
<td>136.6</td>
<td>93.3</td>
<td>101.6</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>rank</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tsay</td>
<td>284.1</td>
<td>267.7</td>
<td>226.0</td>
<td>178.3</td>
<td>178.3</td>
<td>104.9</td>
<td>90.0</td>
<td></td>
</tr>
<tr>
<td>rank</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

* No data for the two Rising tones were available in Lin's study.

Lin found significant durational differences among the five non-Rusheng tones using a one-way ANOVA. The five tones are ranked, from longest to shortest, as follows: Rising > High > Mid > Falling > Low. Lin reports that there was no significant difference among Rising, High, and Mid, but both Falling and Low were significantly shorter than the other three tones. It thus seems these five tones can be divided into two groups: the longer three tones (Rising, High, Mid) vs. the shorter two tones (Falling and Low).

Tsay (in preparation) very similar findings. The ranking of durations from longest to the shortest was almost identical to Lin's results: Rising > High > Mid > Falling = Low. An analysis using a one-way ANOVA showed that there were significant differences among the seven tones (F(6,483)=443.92, p<0.001). Scheffe's test showed that, except for pairs High-Rising and Falling-Low, all other pairings of the five non-Rusheng tones were significantly different at the 0.01 level. (The two Rusheng tones will be discussed in Section 4.1 below.) Falling and Low were both significantly different from the other three tones.

While such duration differences surely have an articulatory basis at some level (e.g., Ohala (1978) shows that falling tones are cross-linguistically shorter than rising tones), it is likely that the particular degrees of differences are to some extent learned. That is, tone-driven duration differences are similar to the vowel duration variation before voiced vs. voiceless consonants or in closed vs. open syllables, which, as pointed out by Chen (1970), can be manipulated or exaggerated, as in the case of English, in spite of a presumed physiological motivation.

Evidence for this view of tone duration comes from comparison of the High, Rising, and Falling tones in Taiwanese and Mandarin. As

<table>
<thead>
<tr>
<th></th>
<th>Rising</th>
<th>High</th>
<th>Mid</th>
<th>Falling</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiwanese (Lin)</td>
<td>146 (1)</td>
<td>143.3 (0.98)</td>
<td>93.3 (0.54)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taiwanese (Tsay)</td>
<td>284.1 (1)</td>
<td>267.7 (0.94)</td>
<td>178.3 (0.63)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mandarin (Tseng)²</td>
<td>471.5 (1)</td>
<td>364.1 (0.77)</td>
<td>328.05 (0.70)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
²Tseng (1990), based on one female speaker of Beijing Mandarin.

Therefore, it is reasonable to believe that the duration contrast among tones in Taiwanese is part of the tonal contrasts in the language which children have to learn while learning the tone categories of the language. If the child has proven to be able to master the tone categories of the language, we should be able to find the same kind of duration contrast in the child speech.

3.2. Xuan's Accuracy Rate for Non-Rusheng Tones
In this section, we show that the child has reached the stage of mastering tone categories. All utterances of Xuan between 2:1 and 2:3 were checked based on the impressionistic transcription described above. The following table shows the accuracy rates for the five non-Rusheng tones in final position in a tone group.

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Mid</th>
<th>Low</th>
<th>Rising</th>
<th>Falling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total tokens</td>
<td>338</td>
<td>273</td>
<td>168</td>
<td>178</td>
<td>526</td>
</tr>
<tr>
<td>Correct</td>
<td>333</td>
<td>268</td>
<td>154</td>
<td>153</td>
<td>509</td>
</tr>
<tr>
<td>Accuracy</td>
<td>99%</td>
<td>98%</td>
<td>95%</td>
<td>84%</td>
<td>97%</td>
</tr>
</tbody>
</table>

Consistent with King's (1980) study, the accuracy rate of Xuan for the five non-Rusheng tones during 2:1–2:3 was very high. The only tone that had an accuracy rate lower than 90% was Rising. This might be due to the relative difficulty of producing a rising tone (Li &
Thompson, 1978; Ohala, 1978). However, an accuracy rate of 84% is still over the threshold of mastery for many studies on child language acquisition in the literature. Therefore, we can assume that Xuan had mastered these five tone categories by 2.3.

3.3. Xuan’s Duration Pattern for Non-Rusheng Tones

The next thing is to check if Xuan also acquired the duration distinctions found in adult speech. One crucial thing for measuring syllable duration is to select the syllables so that they have identical segments, i.e. are minimal pairs that differ only in tone. Since the child’s data came from spontaneous speech, it was difficult to find minimal pairs. Another difficulty with using spontaneous speech was that many syllables were merged with either the coda of the preceding and/or the onset of the following syllable, especially when adjacent segments across the syllable boundary were sonorants. These tokens were discarded due to segmentation difficulties. Therefore, not only we did not have the same number of tokens per tone, we also did not have many tokens. The following table gives the mean durations of the vowel i with the five non-Rusheng tones in Xuan’s speech.

### Table 5. Mean durations (msec) of five tones (Xuan)

<table>
<thead>
<tr>
<th>Tone</th>
<th>High</th>
<th>Mid</th>
<th>Falling</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokens</td>
<td>7</td>
<td>12</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Duration</td>
<td>325.3</td>
<td>312.8</td>
<td>267.7</td>
<td>236.7</td>
</tr>
<tr>
<td>108.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Before statistic analysis, the size of the samples was controlled so that each had the same number of tokens (6 data points were chosen at random from the Rising, High, and Falling sets to match the number of Low and Mid tones). The results were very similar to the duration pattern found in adult speech. A one-way ANOVA showed a significant effect of duration (F(4,25)=8.74, p<0.001). High, Rising, and Mid were longer than Falling and Low. Scheffe’s test showed that the differences between High and Low and between Rising and Low were significant at the 0.01 level and the difference between Falling and Low was significant at the 0.05 level. The other pairs did not show significant differences. Third, as shown in (7), the ranking of duration from longest to shortest was the same as the adult speech in Tsay’s study and very similar to the adult speech in Lin’s study.

### Table 6. Durations (in msec) in Child Speech vs. Adult Speech

<table>
<thead>
<tr>
<th>Tone</th>
<th>High</th>
<th>Rising</th>
<th>Mid</th>
<th>Falling</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xuan (child)</td>
<td>312.8</td>
<td>325.3</td>
<td>267.7</td>
<td>236.7</td>
<td>108.7</td>
</tr>
<tr>
<td>rank</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Lin (adult)</td>
<td>143.3</td>
<td>146</td>
<td>136.6</td>
<td>93.3</td>
<td>101.6</td>
</tr>
<tr>
<td>rank</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Tsay (adult)</td>
<td>267.7</td>
<td>284.1</td>
<td>226.0</td>
<td>178.3</td>
<td>178.3</td>
</tr>
<tr>
<td>rank</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

It seems clear that the child also maintains the duration contrasts, in addition to pitch contrasts. However, this phenomenon could still be the effect of articulation, rather than that of abstract categorization. In the next section, we provide further evidence for the duration contrast being learned rather than intrinsic.

4. The Shortness of Rusheng as Part of the Tonal Contrast

There are two Rusheng tones in Taiwanese: Yin Ru (mid abrupt) and Yang Ru (high abrupt). The most salient characteristic of Rusheng are its short duration and the fact that it always co-occurs with syllables with a stop coda. These two characteristics are obviously closely related; tone cannot be articulated on /p, t, k, q/ and tones appearing in syllables with such codas are necessarily short. Therefore, there are three aspects of a target syllable with Rusheng that the child has to master at the same time: the pitch contour, the coda consonant, and the duration.

In this section, we first present acoustic data for the duration of Rusheng in adult speech to confirm the duration pattern. Then we present Xuan’s accuracy rate for Rusheng based on transcriptions, showing that Xuan had not mastered Rusheng by the age of 2.5. Finally, using results from acoustic measurements, we show that Xuan had mastered the duration parameter of Rusheng, although he was still having trouble articulating the coda stop.

4.1. The Shortness of Rusheng in Adult Speech

Previously acoustic studies on Taiwanese tones (Weingartner, 1970;
Liu, 1983) did not measure Runcheng tones. The ANOVA described in 1.1 based on the measurements of Tsuy (in preparation) showed that Yee Ru and Yang Ru were not significantly different at the 0.05 level. But they both were significantly different from the five long tones at the 0.01 level. Thus the shortness of Runcheng in adult speech is confirmed. In terms of syllable structure, this also means that syllables with a stop coda (e.g., ok or aq) were shorter than open syllables (e.g., o).

4.2. The Acquisition of Runcheng

There seems to be no controversy about Runcheng's being acquired later than non-Runcheng in Taiwanese. As noted earlier, King (1980) reports that the child did not master Runcheng until about 3-5, much later than 2-3 for the five non-Runcheng tones. The judgment for the late acquisition of Runcheng was mainly due to the child's dropping the coda stop of the checked syllables. King also observed lengthening in duration of the syllable when the coda was dropped, but provided no acoustic data.

In the case of Xuan, among the 146 Runcheng tokens (juncture only) in his speech between 2.1 and 2.3, 51% of them had coda dropping. Coda dropping is very common in early phonology acquisition, especially in a stage when segment acquisition is still in progress (King, 1980; Su, 1985; Hsu, 1989; So & Dodd, 1995). This might be due to physiological development when motor control in the production of consonants is still developing (e.g., Kent & Miolo, 1995).

Of most relevance to this paper is the following question. When coda dropping occurs and the syllable becomes an open syllable, is the shortness of Runcheng maintained, or is the Runcheng syllable lengthened as if it had a long tone? Under the gestural view of phonological categories, what the child is trying to do is to capture the whole phonetic target. Therefore, although the child is dropping the coda involuntarily, the shortness characteristic of Runcheng in adult speech should be maintained by the child in spite of the lack of a coda. The only effect that the coda dropping may have on duration is a minor (and gradient) compensatory lengthening caused by changing from a closed syllable to an open syllable. However, this lengthening should not cause the checked syllable to become as long as a true open syllable.

The involuntary dropping of the coda in such cases contrasts sharply with the rule-governed dropping of the glottal stop in the adult system. In this process of Glottal Stop Deletion, a coda glottal stop is deleted when followed by another syllable within a tone group (e.g., Tsuy, 1989). Examples are given in (2). Note that as the syllable changes from a closed syllable to an open syllable, the Runcheng tone also changes into a non-Runcheng tone. That is, a Yi or Ru tone (2a) becomes a Falling tone (2b), and a Yang Ru tone (2c) becomes a Low tone (2d). Deletion only occurs with a glottal stop but not other stops, as shown in (2e) and (2f) where coda k is maintained.

(2) a. peq to 'pear'
   b. pek3 pek13 'skin'
   c. peq 'white'
   d. pe k1 stq 'white color'
   e. thak1 'read'
   f. thak1 tenq3 'read book, study'

Since Glottal Stop Deletion is a grammatically specified alternation, the representation of the target syllable for adults does not include a coda and the phonetic target of this syllable for the child should be an open syllable. Therefore, we expect the duration of the target syllable to be the same as in underlying open syllables.

In summary, we predict that checked syllables Vq should be significantly shorter than open syllables V (3a), and should not be significantly different from a checked syllable with coda dropping Vh (3b) because for the child the gestural target is still Vq. For the same reason, Vh should be significantly different from V (3c). By contrast, the duration of a checked syllable with Glottal Stop Deletion V(q) should not be significantly different from that of an open syllable V because the gestural target of V(q) is an open syllable (3d), but it should be significantly different from a checked syllable without stop deletion VC (3e). ( - significantly different; = not significantly different)

(3) Predictions of syllable durations
   a. Vq = V
   b. V(q) = Vh
   c. Vh = V
   d. V(q) = V
   e. V(q) = VC
Results from acoustic measurements support these predictions, as shown below.

4.3. Xuam’s Duration Patterns of Ruanheng Tones

Minimal pairs of syllables were selected from Xuam’s recordings. Due to the limitations of uncontrolled spontaneous data, it was quite difficult to find tokens with the contrasts being examined. The following two tables show the mean durations of syllables with the rime -a.

Table 7 shows duration contrasts in juncture position with different syllable types. There were three types of syllables compared in juncture position: open syllable V, checked syllable with a glottal stop coda Vq, and checked syllable with vocoid shuipping V'.

| syllable type | V | Vq | V'
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>rime -a</td>
<td>25</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>token</td>
<td>279.96</td>
<td>148.6</td>
<td>203.6</td>
</tr>
</tbody>
</table>

A one-way ANOVA was done for the three syllable types. The size of the samples was controlled so that in the samples being compared there were the same number of tokens. For example, there were 5 measurements for the Vq group and 37 for the V' group. Therefore, 5 out of the 37 measurements from the V' group were chosen randomly to match the sample size of the other group. The results showed that there was a significant effect across syllable types (F(1,13)=22.62, p<0.001). Scheffe’s test showed that there was a significant difference in the pairs Vq ≠ V and V' ≠ V at the 0.01 level, as we predicted (3a) and (3c). However, there was no significant difference in the pair Vq = V', confirming our prediction (3c).

Another set of syllables in context position were compared: open syllable V, checked syllable with Glottal Stop Deletion V(q), and checked syllable with a non-glottal stop VC which does not undergo stop deletion. The mean durations of each type of syllables are given in Table 8. Because there were no syllables with the rime -ak in the data collected, syllables with the rime -a were selected for comparison of V and VC.

<table>
<thead>
<tr>
<th>syllable</th>
<th>V</th>
<th>V(q)</th>
<th>V'</th>
<th>VC</th>
</tr>
</thead>
<tbody>
<tr>
<td>rime -a</td>
<td>-a</td>
<td>-a(q)</td>
<td>-a</td>
<td>-ak</td>
</tr>
<tr>
<td>token</td>
<td>25</td>
<td>37</td>
<td>36</td>
<td>16</td>
</tr>
<tr>
<td>mean</td>
<td>192.4</td>
<td>166.9</td>
<td>176.9</td>
<td>112.2</td>
</tr>
</tbody>
</table>

Two-tailed t-tests were done to compare -a with -a(q) and -a with -ak. The size of the samples was controlled the same way mentioned above. The results showed that there was no significant difference between the checked syllables with Glottal Stop Deletion and open syllables (t(1)=0.61, p>0.5), i.e., V(q) = V, as we predicted (3d). There was a significant difference between open syllables and checked syllables with non-glottal stop (t(15)=3.45, p<0.01), i.e., V ≠ VC, also as predicted (3c). Similar results were found for syllables with the vowel -i (see Tsay & Huang, 1998, for details).

In summary, we have shown in this section that the child indeed kept the shortness of Ruanheng regardless of the lack of coda. The child actually mastered duration contrasts earlier than the syllable structure aspect of Ruanheng.

5. Conclusion

In this paper, we argue that children in early stages treat phonological categories as gestural wholes. Not only are contrasts of core phonetic parameters maintained, but also contrasts of redundant phonetic parameters. Using Taiwanese tonal system as a testing domain, we have demonstrated that duration contrasts existing among different tones are maintained by children. Even when the child had trouble articulating, he was still able to maintain the duration contrasts of the tone categories.

Notes
* I thank James Myers for helpful comments on earlier versions of this paper. I also want to thank my research assistants, Ting-Ya Huang, Hsi-Chuan Liu, and Xiao-Jun Chen, for helping with data collection and some of the acoustic measurements. The research was funded by the National...
Another Southern Min (Minnan) dialect that has been described in the literature is Amoy (also called Xiamen or Hage), which has a sound system almost identical to Taiwanese (e.g., Lo, 1930; Bodman, 1935; Tung et al., 1967; Sung, 1973; Chen, 1987).

Yin Qu is described as a low falling tone in some studies (e.g., Lo, 1930; Cheng, 1966; Yang, 1991; Zhang, 1993) and as a low tone in others (e.g., Lin, 1988; Tung et al., 1967; Du, 1988; Tieng, 1955), which consider the slight onglide merely a physiological effect of reaching the low pitch target (Maddieson, 1978b).

Tsai (1999) has argued that duration differences between piratical and non-final positions provide a crucial cue to syntactic structure for young children learning Taiwanese, a case of phonological bootstrapping.

The data of Xuan are part of a large corpus of Taiwanese child language acquisition (TAICORP) being prepared in the CHILDES format (MacWhinney, 1995) by the author.

Oxomatopoeia and kinship terms, which usually have their own tonal patterns, were excluded from analysis.

Du’s (1988) duration measurements used a different scale and was not compatible with other studies.

Some mastery criteria used in the literature: 50% correct (Olmsted, 1971), 70% (Su, 1985), 75% (Templin, 1957; Prather et al., 1975; Art & Goodman, 1976), 80% (Mower & Burger, 1991) and 90% (Hu, 1989).

Mandarin does not have checked syllables or Rusheh tones due to historical sound change (e.g., Pulleyblank, 1978; Li, 1980; Norman, 1988). Although Cantonese has three Rusheh tones, Tse (1978) does not report special observations about Rusheh, but rather collapses them with the other three non-Rusheh tones which have similar pitch height when making generalizations about the child’s tone acquisition.

The results reported in this section were presented with a different focus in Tsai & Huang (1998).

References


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