The Production of Lexical Tones with Phonation Contrasts in Kunshan Wu Chinese by School-Age Children

Wenwei Xu[1], Chunyu Ge[1], Wentao Gu[2] & Peggy Mok[1]

[1]The Chinese University of Hong Kong; [2]Nanjing Normal University

charliexu@link.cuhk.edu.hk

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香港中文大學
The Chinese University of Hong Kong

INTRODUCTION

1. The acquisition of lexical tones involving **creaky voice**
   a) studied in Mandarin T3/T4 [1] and Cantonese T4 [2]
   b) creakiness believed to be phonetically motivated by the low pitch targets [3]
2. However, **non-modal phonation** in tonal languages can also be phonologically motivated, e.g. **breathy voice** in White Hmong [4] and Wu Chinese [5], lax voice in Southern Yi [6]
3. Wu Chinese features contrastive tone registers correlated with pitch and voice quality in the word-initial position [5]
   a) upper register tones = vowel in modal voice
      lower register tones = vowel in **breathy voice**
   b) our earlier acoustic study has confirmed such phonation contrast in the adult production of Kunshan Wu [7].
4. Non-modal phonation can be an important cue in the production, but its acquisition remains unexplored, so this study aims to fill the research gap by investigating school-age children's (7;2–10;4) production of Kunshan Wu tones.

METHOD

1. Speakers: six Mandarin-Wu bilingual children (3M, 3F)
2. Materials
   a) 73 monosyllabic words in isolation
   b) Onset: obstruents /p b t d k g f v s z tɕ dʑ/
   c) Vowel: /a, ɛ, i, ɔ/
   d) Tone: five unchecked tones

Tone	Upper (a) = Modal	Lower (b) = Breathy
	/ka/	/ga/
***Ping* (1)**	加 'plus' (mid-level)	茄 'eggplant' (rising)
***Shang* (2)**	假 'fake' (falling†)	解 'loosen' (low dipping)
***Qu* (3)**	嫁 'marry' (high-dipping†)	

Table 1: Example words from the recording materials.
(†Tone merger between T2a & T3a found among the adults in [7])

3. Auditory judgment conducted by the first and second authors, a native speaker of Kunshan Wu and one of another Wu dialect, who decided whether each token sounded breathy.
4. Tone-space dispersion (TD) calculated according to [8].
5. Acoustic measures extracted from VoiceSauce [9]
   a) spectral tilts: H1-H2, H2-H4, H4-H2K, H2K-H5K, H1-A1, H1-A2, H1-A3, H1-H4, H1-H2K, H1-H5K (all corrected for formant influence)
   b) noise: Cepstral peak prominence (CPP), the harmonics-to-noise ratios (HNR) in 0-500/1500/2500/3500Hz

RESULTS

1. Tone merger was mostly unidirectional (T3a > T2a, see Table 2), cf. bidirectional for the adults in [7]
   a) merger complete for the child M3
   b) incomplete for the others (Boschloo's tests: $p < 0.027$)
2. Auditory judgment (see Table 2) showed that every child was more likely to produce breathiness for the lower register than for the upper register (Cohen's Kappa = 0.58, Boschloo's tests: $p < 0.001$)

ID	Age	TD	Tone merger		R1's judgment		R2's judgment	
			T2a > T3a	T3a > T2a	Upper breathy	Lower breathy	Upper breathy	Lower breathy
F1	7;2	2.02	0%	33.3%	37.1%	95.7%	8.6%	56.5%
F2	8;4	2.22	5%	50.0%	13.5%	89.4%	4.1%	71.2%
F3	9;10	2.84	0%	51.3%	3.5%	80.0%	1.8%	59.0%
M1	7;7	3.49	0%	60%	10.0%	50.0%	3.3%	61.5%
M2	8;6	2.79	20.0%	11.5%	11.1%	42.6%	4.2%	50.0%
M3	10;4	2.53	0%	100%	4.5%	96.1%	1.8%	67.6%

Table 2: Age, TD, tone merger and auditory judgment results.

3. The children's F0 contours fairly resembled the adults'.

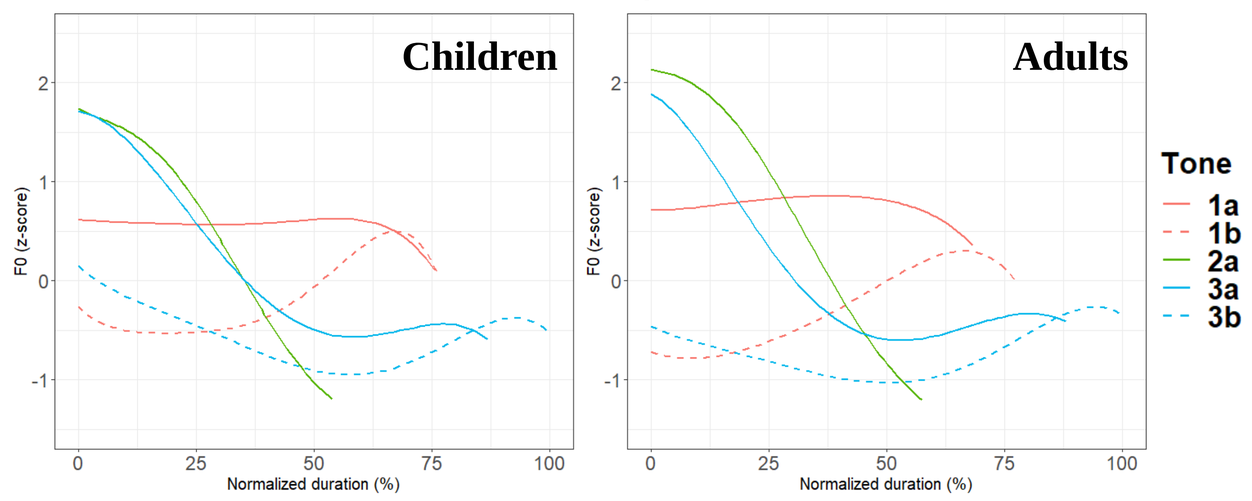

Figure 1: F0 contours of the lexical tones.

4. The lower register tones (pointed by arrows in Figure 2) showed **higher spectral tilts** & **more noise**.

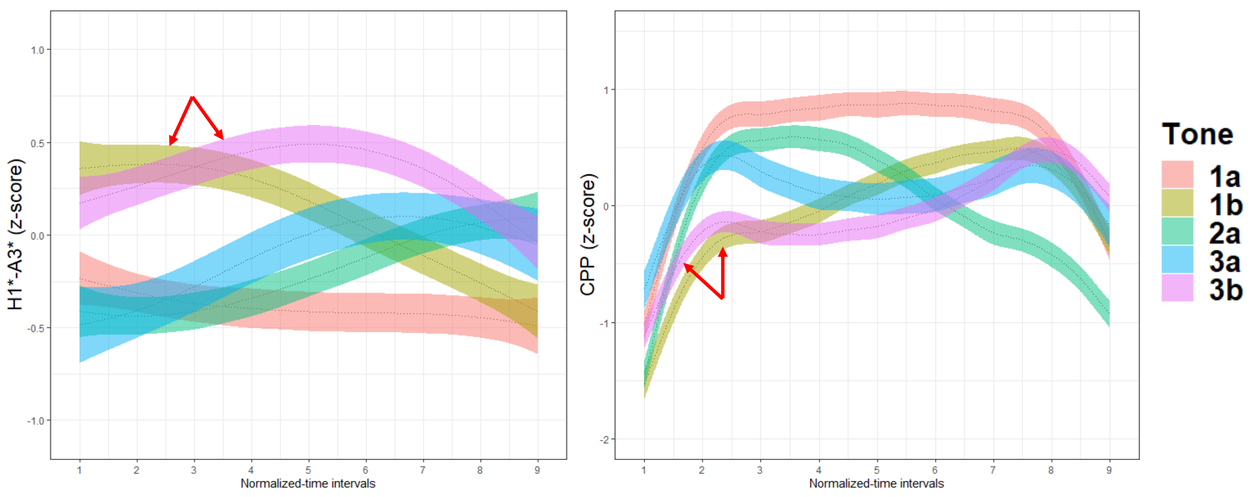

Figure 2: SSANOVA of the acoustic correlates.

DISCUSSION & CONCLUSION

1. The acoustic correlates showed that the lower register tones were breathier than the upper register tones in the children's production.
2. The child F1, for example, showed simultaneously
   a) smallest tone-space dispersion
   b) higher accuracy in distinguishing merging tones
   c) lower accuracy in producing the phonation contrast
3. Therefore, the acquisition of **tonal categories**, **pitch** and **voice quality** is not necessarily parallel and concurrent, and there may not be a single indicator of the development of the lexical tones.

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