

DEVELOPMENTAL CHANGE OF F₀ IN CANTONESE-SPEAKING PRE-ADOLESCENT CHILDREN

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ABSTRACT

This paper presents the developmental fundamental frequency (F₀) data from Cantonese-speaking pre-adolescent children, male and female. Results of frequency analysis of the speech data from children of nine age groups from 4 to 12 years show that (i) there is an overall drop in F₀ across the nine age groups of both genders and a larger change for male than female children; (ii) a significant difference in F₀ between male and female children emerges at age 12 as a result of a large F₀ drop in male but not female children; (iii) the F₀ for male children of age 12 is half an octave higher than that for male adults, but the 12-year-old female children reach the adult-like F₀ pattern; and (iv) the patterns of developmental F₀ between Cantonese-speaking and English-speaking children are similar, except for the differences in the F₀ drop between age 5 and age 6 and in the 12-year-old male children between the two languages.

Keywords: fundamental frequency (F₀), Cantonese, pre-adolescent children, age, gender

1. INTRODUCTION

Fundamental frequency (F₀) is a major acoustic attribute of speech which contains the indication of transition from childhood to adulthood and the distinction between male and female voices. A number of acoustic studies of the developmental change of F₀ in children's speech have reported that the F₀ drops as age increases ([1, 2, 3, 4, 6, 7, 8, 9]). A large decrease in F₀ is observed in the speech of early childhood between the 3- and 6-year-old children ([4]), and the decrease levels off after 6 years of age ([1, 2, 3, 4, 6, 8, 9]). It is also reported that the age-related F₀ drop is true for both male and female pre-adolescent children from 5 to 10 years of age, and the change tends to be more gradual and less apparent in female than male children ([6, 9]). There is no significant change of F₀ in female children older than 12 years of age, and the difference in F₀ is at the minimum between female children of 12 years of age and

female adults ([4, 9]). As for male children, there is a large difference in F₀ between the ages of 11 and 18 ([3, 4, 7, 9]). The F₀ in the 13-year-old male children is approximately an octave higher than the F₀ in male adults ([4]), and between male children of 14 and 18 a large drop in F₀ is observable ([3]). The developmental F₀ data show that voice change in preadolescent children reaches completion earlier in female than male children, and between the two genders, there is no significant difference in F₀ under the age of 13 ([1, 2, 4, 5, 8, 9]). A gender difference in F₀ is observed in the 14- or 15-year olds due to a large F₀ drop in male children ([8]).

Nearly all of the past developmental studies of F₀ change were based on speech data from speakers of English. The present study investigates (i) the F₀ from pre-adolescent male and female children of Cantonese; (ii) the age- and gender-related developmental change of F₀; and (iii) cross-language similarities and differences in F₀ between Cantonese-speaking and English-speaking children.

2. METHOD

2.1. Test Material

There are nine citation tones in Cantonese, six long [55 33 22 21 25 23] and three short [5 3 2] ([10]). Meaningful test monosyllabic words containing the vowel [a] and associated with each of the nine tones were used as test materials (Table 1).

Table 1: Test monosyllabic words associated with the nine Cantonese tones.

Long tones	Test syllables	Short tones	Test syllables
[55]	[pa ⁵⁵] 'father' 爸	[5]	[k ^h ak ⁵] 'card' 咭
[33]	[p ^h a ³³] 'fear' 怕	[3]	[pat ³] 'eight' 八
[22]	[ha ²²] 'below' 下	[2]	[pak ²] 'white' 白
[21]	[p ^h a ²¹] 'to climb' 爬		
[25]	[ta ²⁵] 'to hit' 打		
[23]	[ma ²³] 'horse' 馬		

The test monosyllabic words were commonly used in everyday speech. A randomized list of the test words in Chinese character was prepared. For younger children who were not yet entirely familiar with written Chinese, pictures illustrating the meanings of the test words were placed alongside the Chinese characters. The F_0 of the nine Cantonese tones were analyzed. In this paper, only the F_0 of a long [55] tone is presented.

2.2. Subjects

The test monosyllabic words were elicited from 90 Cantonese-speaking preadolescent children, male and female, who were kindergarten or primary school pupils in Hong Kong. The children were in nine age groups from 4 to 12 years, with five males and five females in each group. Also recorded were speech data from five Cantonese-speaking male and five female young adults in their early 20s. All the speakers were born in Hong Kong and grew up in a monolingual Cantonese-speaking family and did not have history of speech and hearing problems.

2.3. Data collection and analysis

Three repetitions of each test word were recorded of the speakers. The recorded speech data were analyzed for F_0 contours, using the pitch synchronized F_0 tracing program available on KayPENTAX CSL (Computerized Speech Lab) 4500 speech analysis software. The F_0 was extracted from the temporal mid-point of the [55] tone.

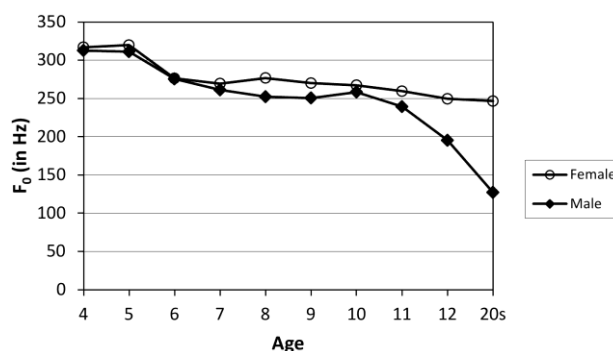
3. RESULTS

The results of the developmental change of F_0 are based on the speech data from five male and five female Cantonese-speaking pre-adolescent children of the nine age groups and the F_0 data from five male and five female adult speakers in their early 20s.

3.1. Developmental F_0 change in Cantonese-speaking children

Figure 1 shows the mean F_0 values for the Cantonese [55] tone on the vowel [a] for male (in dark diamond) and female (in empty circle) children of the nine age groups of 4 to 12 years and young adults in their early 20s. For each speaker, the F_0 values were averaged across three repetitions, and for each age and gender group, the F_0 values were averaged across five speakers.

Figure 1: Mean F_0 values for Cantonese-speaking male and female children of nine age groups of 4 to 12 years and male and female adults in their early 20s.



As can be seen in Figure 1, for children of 4 to 12 years of age, male or female, there is a tendency for the F_0 to drop as the age increases. The F_0 drop across the nine age groups is significant ($p < 0.001$) for both genders. The highest F_0 values are observed at age 4 and age 5 for both male (312.69 Hz and 311.24 Hz, respectively) and female (316.96 Hz and 319.87 Hz, respectively) children. A large drop in F_0 occurs at age 6 to 275.52 Hz for male children and 283.01 Hz for female children, and the F_0 drop between age 5 and age 6 is significant for both male ($p < 0.05$) and female ($p < 0.005$) children.

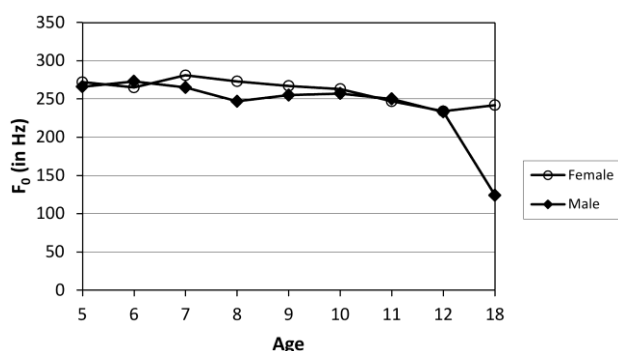
Figure 1 also shows that the F_0 drop levels off after age 6. For male children, the change of F_0 from age 7 (261.28 Hz) to age 11 (239.43 Hz) is progressive and the difference is non-significant. However, at age 12, there is a large drop in F_0 to 195.33 Hz and the change is significant ($p < 0.005$). The data suggest that the voice change in preadolescent male children commences between age 11 and age 12. As for female children, throughout the ages between 7 and 12 the F_0 change is gradual from 269.50 Hz to 249.68 Hz and the difference non-significant.

A comparison of the F_0 data between children and adults in their early 20s (Figure 1) shows there is a substantial difference in F_0 between male children of any ages and male adults, and the differences are all significant ($p < 0.001$). A significant difference in F_0 is observable only between female adults and female children of ages 4 ($p < 0.001$), 5 ($p < 0.001$), 6 ($p < 0.005$), and 8 ($p < 0.05$). The F_0 for female children of 12 years of age (249.68 Hz) and that for female adults in their early 20s (246.70 Hz) are almost the same. For the 12-year-old male children, the F_0 is half an octave (195.33 Hz) higher than that for male adults

(127.17 Hz). The data suggest that the adult-like F_0 pattern is reached earlier in female children than male children.

The pattern of the developmental F_0 change in Cantonese-speaking children is also observable in the speech of English-speaking children ([9]), with a few differences. Figure 2 shows the F_0 on the English vowel [a] for (i) English male (in dark diamond) and female (in empty circle) children of eight age groups of 5 to 12 years and (ii) 18-year-old young adults ([9]).

Figure 2: The F_0 for English-speaking male and female children of eight age groups of 5 to 12 years and for 18-year-old male and female adults (Lee, et al. [9]).



A comparison of Figure 1 and Figure 2 shows the English and Cantonese F_0 data are similar. The F_0 also drops with an increase in age for English-speaking children, both male and female. However, a large drop in F_0 between age 5 and age 6 in Cantonese-speaking children (Figure 1) is not observed in English-speaking children (Figure 2). Overall, the drop in F_0 throughout the pre-adolescent years (4/5 to 12) is smaller and more gradual for English-speaking than Cantonese-speaking children.

For both English-speaking and Cantonese-speaking children, the F_0 is smaller for the age group of 12 years than any other age groups of the same gender. Also true for both English and Cantonese is that the substantial difference in F_0 between male adults and male children of any age groups is not observed between female adults and female children.

For comparison purpose, the ratios of the F_0 for children of different age groups to the F_0 for adults of the same gender for Cantonese and English speakers were obtained and presented in Table 2. For any age groups, the F_0 ratio is smaller between female children and female adults than between male children and male adults. This indicates that

the F_0 is closer to the adult-like F_0 pattern for female children than male children of all ages. The ratios which are close to '1' indicate that the F_0 in children is nearing the adult-like F_0 pattern.

Table 2: Ratios of the F_0 for children of different age groups to the F_0 for adults of the same gender for Cantonese (this study) and English (Lee, et al. [9]); '—' denoting absence of F_0 data; MC = male children, FC = female children, MA = male adults, FA = female adults.

Age	Cantonese		English	
	MC/MA	FC/FA	MC/MA	FC/FA
4	2.46	1.28	—	—
5	2.45	1.30	2.15	1.12
6	2.17	1.12	2.20	1.10
7	2.05	1.09	2.14	1.16
8	1.98	1.12	1.99	1.13
9	1.97	1.10	2.06	1.10
10	2.03	1.08	2.07	1.09
11	1.88	1.05	2.02	1.02
12	1.54	1.01	1.88	0.97

The F_0 ratios between Cantonese male children and male adults range from 1.54 to 2.46. The F_0 ratio between the 12-year-old Cantonese male children and male adults is the smallest (1.54). The F_0 ratios between male children and male adults range from 1.88 to 2.20 for English. The F_0 ratio between the 12-year-old English children and male adults is also the smallest (1.88). For Cantonese and English male children, the F_0 is approximately a half to one octave larger than that for male adults.

As for female speakers of the two languages, the F_0 ratios between children and adults are 1.30 or less for Cantonese and 1.16 or less for English (Table 2). The F_0 ratios also decrease with an increase in age for female children, but the F_0 ratio range is smaller, 1.01 to 1.30 for Cantonese and 0.97 to 1.16 for English. For both Cantonese and English, the F_0 ratios for female children of all the age groups, except for the English age group of 12 years, are only slightly larger than those for the female adults, and the F_0 ratios are close to '1' for female children of age 11 or age 12. The F_0 data suggest that for both female Cantonese-speaking and English-speaking children, the adult-like F_0 pattern is reached at age 11 or 12. For both Cantonese and English, the developmental F_0 change is smaller and the F_0 reaches the adult-like F_0 pattern earlier for female children than male children.

3.2. Differences in developmental F_0 change between children of two genders

Table 3 presents the F_0 ratios between female and male children of the same age, plus the F_0 ratio between female and male for Cantonese adults (this study) and English adults (Lee, et al [9]).

Table 3: F_0 ratios between female and male children of the same age and F_0 ratios between female and male adults for Cantonese (this study) and English (Lee, et al. [9]); ‘—’ denoting absence of F_0 data.

Age	Female children/Male children	
	Cantonese	English
4	1.014	—
5	1.028	1.023
6	1.003	0.971
7	1.031	1.060
8	1.097	1.105
9	1.078	1.047
10	1.035	1.023
11	1.084	0.988
12	1.278	1.004
20s	1.940	1.952

For children of any age groups, the F_0 ratio between female and male is near ‘1’, indicating that the difference in F_0 is at the minimum between male and female children. An exception is the Cantonese age group of 12 years, with a larger F_0 ratio of 1.278 between female and male children, due to a drop in F_0 in the 12-year-old male children (Figure 1). The data suggest that the emergence of an observable difference in F_0 between Cantonese male and female children is at the age of 12. The gender difference in F_0 however is not observed in English children of the same age (Table 3 and Figure 2), suggesting that the emergence of the gender difference in F_0 for English children is beyond the age of 12.

The F_0 ratios between female and male adults for Cantonese and English (Table 3), that is, 1.940 and 1.952, respectively, are much larger than those between male and female children of any age groups. For both languages, the F_0 for female adults is about an octave higher than the F_0 for male adults.

4. SUMMARY AND CONCLUSION

This paper has presented the developmental F_0 data from Cantonese-speaking children, male and

female, of nine age groups from 4 to 12 years. The findings in this study are in general similar to those reported in the literature [1, 2, 3, 4, 5, 6, 7, 8, 9]. In summary, (i) there is an overall drop in F_0 across the nine age groups of both genders and a larger F_0 change in male than female children; (ii) at age 12, a large difference in F_0 between male and female children emerges as a result of a large F_0 drop in male but not female children; (iii) the F_0 is half an octave higher for the 12-year-old male children than male adults, but the 12-year-old female children reach the adult-like F_0 pattern; and (iv) the patterns of developmental F_0 between Cantonese-speaking and English-speaking children are similar, except for the differences in the F_0 drop between the 5- and 6-year-old children and in the 12-year-old male children of the two languages.

5. ACKNOWLEDGEMENTS

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