

六歲前母音空間長期發展：年齡及性別相關的差異

Development of vowel acoustic space before 6 years of age: age- and sex-related changes

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摘要

本研究報告是母音長期發展歷程第六階段研究結果。本階段研究長期追蹤兩位在中文環境中的兒童，在6歲之前的母音變化過程，分析各主要母音類型的第一共振峰及第二共振峰的長期變化。這個時期的研究結果顯示：1)雙母音使用仍然最頻繁，這代表小孩此時對舌頭作靈活準確的控制更熟練，這也反應母語中雙母音的高出現率；2)母音加鼻音韻尾出現頻率僅次於雙母音，一直到6歲男孩使用頻率仍低於女孩。女孩早在2歲9個月就開始持續大量使用這類母音，然而男孩到4歲3個月才開始持續增加使用頻率；3)延續前一階段觀察結果，男孩的母音 F_1 及 F_2 平均值從3歲6個月起開始偏低發展，在6歲前這個階段持續下降，但不如上一個階段明顯。女孩的 F_1 及 F_2 平均值在這兩個階段仍然持續變動，並無穩定下降現象，這更確認前一階段發現的性別差異的起始點及發展趨勢；4)各母音 F_1 及 F_2 值變異性持續下降，漸趨穩定；5) F_1 - F_2 母音空間面積漸漸縮小集中；6) f_0 自一歲後持續下降，在男孩尤其明顯。長期的聲學分析及語音記錄可用來描述生理結構以及聲學參數值的相依性，協助構音障礙臨床診斷及治療計畫。

關鍵字：母音習得、共振峰頻率、母音空間面積

Abstract

The present study is the sixth year of a longitudinal observation of the vowel production in Mandarin-learning children. Major findings in the sixth year are: 1) Diphthongs continue to show the highest frequency at this stage, reflecting the phonological system of the ambient language; 2) The frequency of vowels with nasal endings is next to diphthongs. Up to this stage, the girl subject still used this vowel category more often than boy subject; 3) Continuing the trend of decreasing vowel formant values found in the previous stage, decrease in F_1 F_2 values in the boy subject is still evident at this stage. However, there is no such an obvious change in formant values in the girl subject. This confirms the emergence and the trend of gender difference found in the previous stage at around 3 years and 6 months of age; 4) Variability of formant frequency decreases with age; 5) Vowel F_1 - F_2 space area reduces over time; 6) A decline of f_0 is found in both subjects, especially for boy subject. The longitudinal analysis of vowel production provides important references for assessment and treatment of articulation disorders in children.

Keywords: Vowel Development, Vowel Formant Frequencies, Vowel Space Area

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INTRODUCTION

Vocalic production in two Mandarin-learning children was investigated from birth to six years old with both perceptual transcription and acoustic analysis. This current study focuses on the development of the sixth year and the continuity in the process.

There is relatively little literature on treatment of vowel disorders. Many children may not receive speech therapy on vowels although there are obvious vowel errors because clinicians tend to treat consonants before vowels. This can be attributed to much more established guideline in assessment and treatment in the intervention for consonant errors than for vowel errors (Stoel-Gamman & Pollock, 2008). The acquisition of vowels is less studied than the acquisition of consonants because vowels are generally regarded to be learned earlier than consonants. Moreover, vowel errors are less frequent than consonant errors in children with phonological impairment (Eisenson & Ogilvie, 1963; Stoel-Gammon & Herrington, 1990). However, according to Pollock and Keiser's (1990) study of 15 children with moderate-to-severe phonological impairment, vowel errors may occur in as many as 50% of children with phonological disorders. Vowel development thus deserves more attention for both research and clinical application. Studies on early vocalic production in both qualitative and quantitative changes can provide more accurate norms for evaluating and helping in the early identification of articulation disorders (Ertmer, 2001).

The growth of vocal tract and its relationship with the development of speech is a complicated process. The relationship between anatomical differences and the differences of speech production would be best studied in vowel production. It is expected that the vowel formant frequency will decrease as vocal tract length increases (Fant, 1960). Moreover, because males and females differ in the length and shape of vocal tracts and boys have a larger vocal tract than girls, there are differences in formant frequencies between preadolescent boys and girls. Perry, Ohde, and Ashmead (2001) and Whiteside and Hodgson (2000) pointed out as early as four years old, boys are found to have lower formant frequencies than those of girls. The differences become more obvious by 7 or 8 years. Namely, gender differences in speech acoustics can be observed in early childhood well before puberty. Chronological age and gender difference are the two major independent variables for studies of maturation, including speech.

METHODOLOGY

Vocalizations of 2 Mandarin-learning children (Subject A, a boy; Subject B, a girl) were audio recorded during observations of their natural daily activities in their homes once every 3 months, from birth to 6 years old. An average of 45 minutes of recordings was made from each of the two-hour observation sessions for each child.

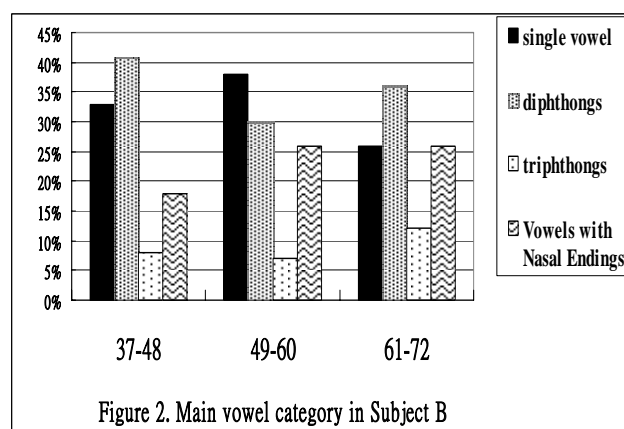
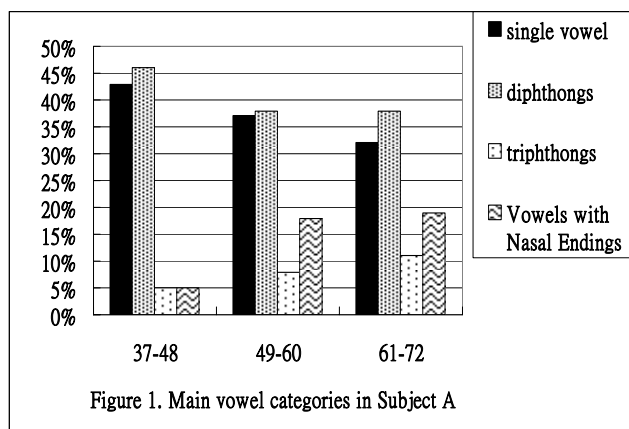
A wireless lapel microphone was linked to a Sony DAT recorder with a signal-to-noise ratio above 91 dB. The DAT recorder was used for playback in perceptual transcription and acoustical analysis. All spontaneous productions were then digitally recorded into a computer using Computerized Speech Lab (Kay CSL 4400). The sampling rate was 48,000 samples per second. The frequency values of the first and the second formants of the vowels were measured with reference to the four displays: narrowband spectrogram, broadband spectrogram, FFT, and LPC.

FINDINGS AND DISCUSSION

DEVELOPMENT OF VOWEL CATEGORIES

There is no obvious change in the distribution pattern of main vowel categories from 5 years to 6 years of age in both subjects. Diphthongs show the highest frequency at this stage in both subjects (see Figures 1 and 2), and almost all of the diphthongs in Mandarin are found. This development indicates that children at this stage have acquired better speech motor

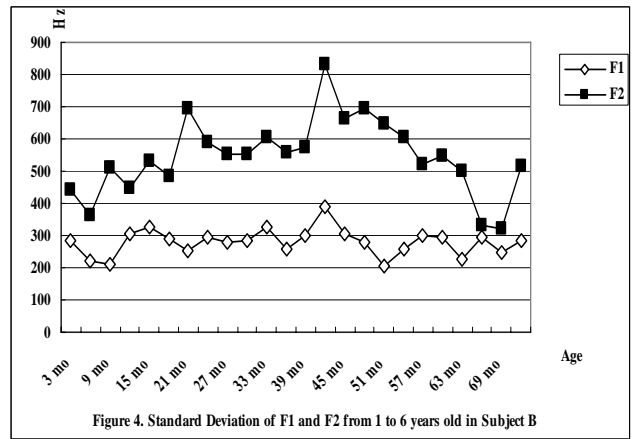
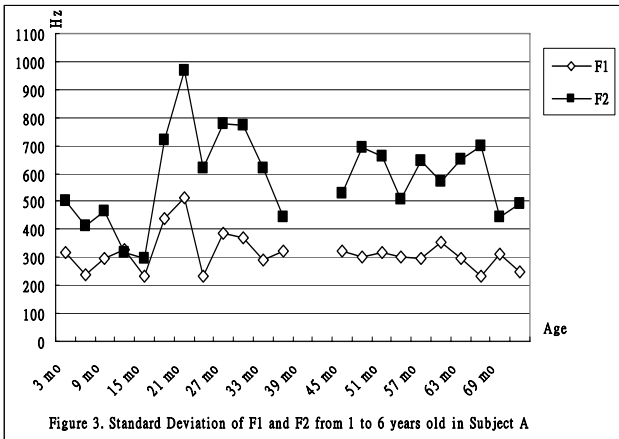
control and timing control in moving from the position of one vowel to the other for producing diphthongs. The frequency of vowels with nasal endings shows prominent increase at 5 years old, and continues to show high frequency at this stage. In the developmental process, girl subject started to use this vowel category frequently as early as 2 years and 9 months of age. Nevertheless, it is not until 4 years and 3 months this vowel category was found to be used frequently in boy subject. Like in the previous stages, Subject B (girl) still uses vowels with nasal endings more frequently (26%) than Subject A (boy) (19%) at 6 years of age. At this stage, vowels with nasal endings show similar frequency as diphthongs in girl subject. However, up to 6 years old, in boy subject vowels with nasal endings still show much lower frequency than diphthongs.



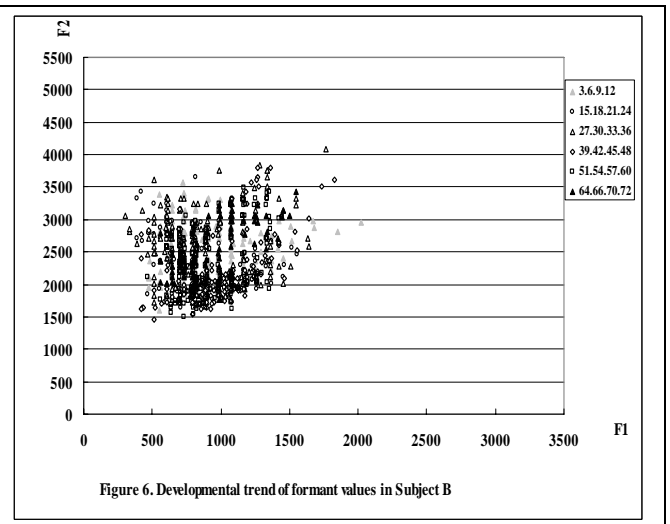
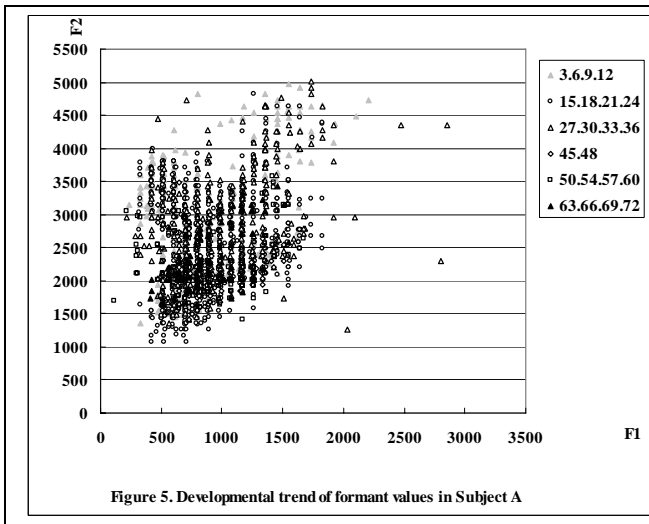
VOWEL FORMANT FREQUENCIES

Continuing the trend of decreasing vowel formant values found in the previous stage, decrease in F1 F2 values in the boy subject is still evident at this stage. However, there is no such an obvious change in formant values in the girl subject. This confirms the emergence and the trend of gender difference found in the previous stage at around 3 years and 6 months of age. In the previous report, we found that, like what was found in Perry, Ohde, & Ashmead (2001) and Whiteside & Hodgson (2000), from 3 years and 6 months, the boy subject (Subject A) shows relatively lower vowel formant values than girl subject (Subject B), reflecting gender differences in the development of vocal tract. This trend is continuously observed in this stage.

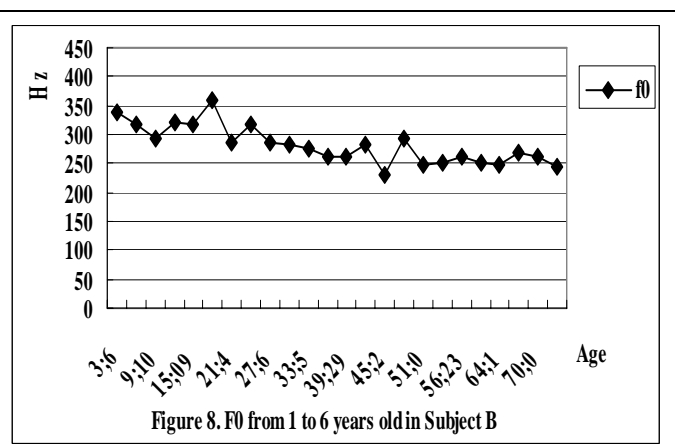
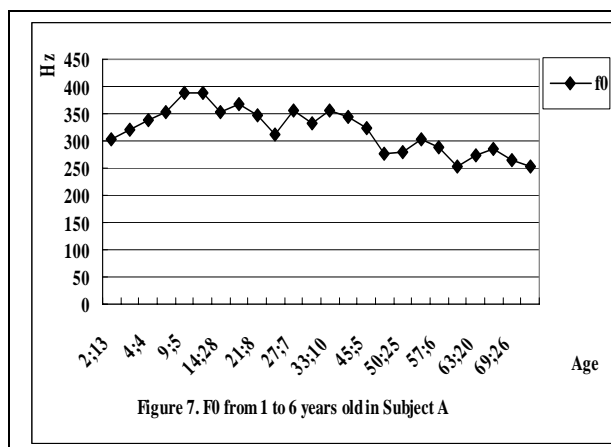
In measuring articulatory variability, standard deviations of F1 and F2 values across ages are calculated. As seen in Figures 3 and 4, in the course of development, there are less variability in F1 values, and more abrupt changes of F2 values in both subjects. The developmental process of mature control in articulatory gesture seems to be complicated with various dimensions. Moreover, a general trend of decrease in variability can be found from 4 years on in both subjects, with more steady decrease in girl subject.



Vowel areas are calculated for vowel triangles with three corner vowels. In boy subject, F1-F2 vowel areas reduce from 614336 Hz² at 4 years old to 358847 Hz² at 5 years of age, at the similar age when abrupt decrease of formant frequency was found. In girl subject, F1-F2 vowel areas decrease from 424268 Hz² at 5 years old to 254299 Hz² at 6 years old. Expand of vowel areas can be found at the early stage of development, followed by reduce of vowel areas at the later stage (5 years old for boy and 6 years old for girl). The broader vowel space at early stages corresponds to the increased variability of vowel formants which might be due to immature motor control (Smith & Goffman, 1998; Green, Moore, Higashikawa, & Steeve, 2000). After acquiring more mature motor control for vowel production, the decreased variability of vowel formants leads to the reduction of F1-F2 space at later stage.



Regarding vocal fundamental frequency of vowel production in different age levels and in both genders, decline of f0 is found in both subjects, especially for boy subject from about 389 Hz at 1 year old to 252 Hz at 6 years old. A less rapid decline is found in girl subject from 321 Hz at 1 year old to 245 Hz at 6 years old. However, gender differences can be better identified in formant frequencies (vocal tract resonator), especially F2, rather than f0 (vocal tract length) (Childers & Wu, 1991).



CONCLUSION

Vowel production in two Mandarin-learning children was recorded in a longitudinal study from birth to 6 years old. Major findings in the sixth year of development are: 1) Diphthongs show the highest frequency at this stage in both subjects; 2) Girl subject used vowels with nasal endings more frequently than boy subject. At this stage, vowels with nasal endings show similar frequency as diphthongs in girl subject; 3) Decrease of F1 F2 values in boy subject is continuously observed in this stage; 4) There are less variability in F1 values, and more abrupt changes of F2 values in both subjects. A general trend of reduction in variability can be found from 4 years on in both subjects; 5) Expand of vowel F1-F2 areas can be found at the early stage of development, followed by reduce of vowel areas at the later stage; 6) A decline of f0 is found in both subjects, especially for boy subject.

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