

Longitudinal development of vowels before four years of age

母音在四歲前長期發展變化

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摘要

本研究報告是母音長期發展歷程第四階段（即 36-48 個月大）的結果。本階段研究長期追蹤兩位在中文環境中的幼兒，在 48 個月大之前的母音學習過程。首先將採集的語料以聽覺轉寫記錄，作語音類別及出現頻率分析。再分析各主要母音類型的 F₁F₂ 值的長期變化。研究結果顯示：1) 中文中單母音已全部出現，出現頻率趨向平均，只有稍晚習得的 /y/ 頻率偏低；2) 雙母音使用最頻繁，這代表小孩此時開始可以對舌頭作較靈活準確的控制，從一個母音滑至下一個母音。此時中文中大部分的雙母音都已出現；3) 母音加鼻音韻尾出現頻率僅次於雙母音，和單母音出現頻率相近。但是有個人個別使用偏好差異；4) 三母音 /iau/ 使用頻率相當高，在幾個階段甚至高於大部分的雙母音；5) 觀察的個案中，和女孩相較，男孩的母音 F₁ 及 F₂ 平均值從三歲六個月起開始偏低發展，這和 Perry, Ohde, & Ashmead (2001), Whiteside & Hodgson (2000) 的發現一致。長期的聲學參數數值，加上語音發展資料，可提供一個較完整的資料庫，來描述母音發展的長期歷程以及生理結構和聲學參數值的相依性。這樣的研究有臨床應用重要意義。

關鍵字：母音習得、共振峰頻率、母音空間

Abstract

The present study is the fourth year of a longitudinal observation of the vocalic production in Mandarin-learning children. Vocalic productions of children aged 36-48 months were audio-taped and analyzed with both perceptual transcription and acoustic measurement. Major findings in the fourth year of development are: 1) Almost all of the single vowels appear and they are evenly distributed except for the late-acquired /y/; 2) Diphthongs show the highest frequency and almost all of the diphthongs in Mandarin are found at this stage; 3) In one of the children observed, vowels with nasal endings are prominent and display similar frequency of occurrence as single vowels; 4) Triphthong /iau/ are frequently found in both children and even show higher frequency than most of the diphthongs; 5) Like what was found in Perry, Ohde, & Ashmead (2001) and Whiteside & Hodgson (2000), from 42 months on, the boy subject shows lower vowel formant values, reflecting gender differences in the development of vocal tract. The longitudinal data on vocalic production provide important references for early identification of articulation disorders in children.

Keywords: Vowel Development, Vowel Formant Frequencies, Vowel Space

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I. INTRODUCTION

This study is designed to investigate the longitudinal developmental process of vocalic production from babbling to speech production in two Mandarin-learning children from birth to four years old with both perceptual transcription and acoustic analysis. This current study focuses on the development of the fourth year and the continuity in the process.

Younger children's vocalizations showed a greater range of variation than those of older children in formant frequency patterns, which ranged from stable and well-defined patterns to rapidly changing ones (Kent & Bauer, 1985; Kent & Murray, 1982; Lieberman, 1980). The major characteristics of the vowel formant patterns in young children's vocalizations present a considerable challenge for measuring formant frequency values. For example, Buhr (1980) and Kent and Bauer (1985) indicated that nasal coupling makes measurement of the second and third formants extremely difficult. Moreover, both nasalization and harmonic doubling, which are usually found with gradual onset and offset, made it difficult to identify acoustic boundaries or transitions among individual segments in early speech.

It is expected that the formant frequency will decrease as vocal tract length increases (Fant, 1960). Moreover, because 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. These gender differences in the formant values are attributed to various dimensions of anatomic changes.

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). Currently available clinical screening tests for children are based on the occurrence of consonants and vowels in the identifiable words they produce (Selby, Robb, & Gilbert, 2000). These tests are not applicable to infants or children who produce no or few identifiable or meaningful utterances. Studies on early vocalic production can help to establish norms for young children and to develop appropriate screening tests for this population. These studies are particularly important in identifying subtle differences in vocalic utterances, which are not readily detectable by human ear, in phonological disordered children to establish definable guideline and to set up goals for speech therapy.

II. METHODOLOGY

This longitudinal study is designed to observe and analyze the spontaneous vocalic production in home environment of 2 Mandarin-learning children spanning the period from birth to 48 months. Children's vocalizations were audio recorded (once every 3 months) during observations of their natural daily activities in their homes. An average of 45 minutes of recordings was made from each of the two-hour observation sessions for each child.

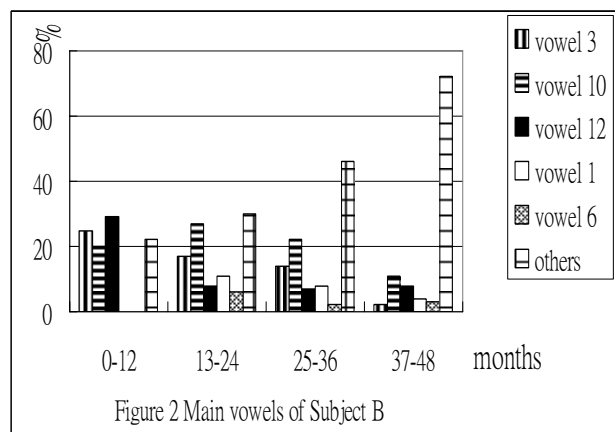
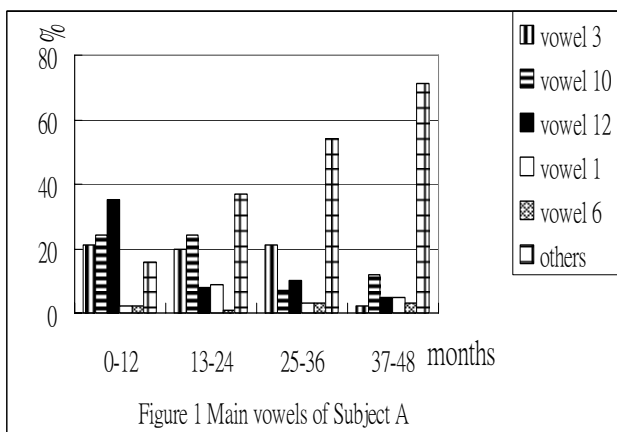
To achieve good quality and flexible recording without distracting the subjects, a wireless lapel microphone was used. The microphone was linked to a Sony DAT recorder with a signal-to-noise ratio above 91 dB. The DAT recorder was used for playback in perceptual transcription and acoustical analysis. All spontaneous productions of V or CV syllables during each of the 45-minute recording were phonetically transcribed. These vowels from DAT tapes were then digitally recorded into a computer using Computerized Speech Lab (Kay CSL 4400). The sampling rate was 48,000 samples per second. Broadband and narrowband spectrograms were generated for each token by adjusting analysis size. The cursor was moved to the steady portion of each spectrogram and a Fast Fourier Transform (FFT) was generated with Linear

Predictive Coding (LPC) overlaid on the Fourier spectrum. 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.

III. FINDINGS AND DISCUSSION

DEVELOPMENT OF VOWEL CATEGORIES

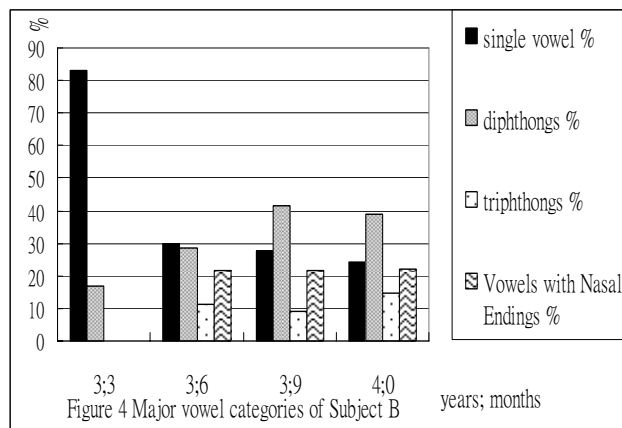
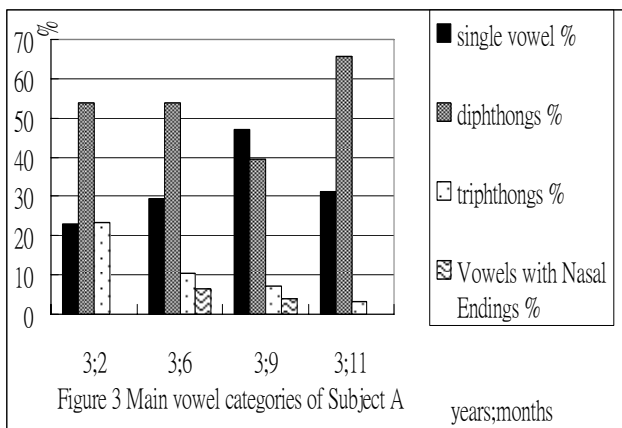
Almost all of the single vowels in Mandarin appear and they are evenly distributed except for the late-acquired /y/. The newly-developed corner vowels /ɪ/ and /ʊ/ in the third year are used more frequently during the fourth year and show similar frequency of occurrence as other single vowels. Although the low vowel shows high frequency of occurrence during the first three years, for Subject B, it is not used more frequently than most of the single vowels in the fourth year. However, for Subject A, the low vowel /a/ is still prominent as was found in the previous three years. This is one of the major differences between the development of these two subjects.



Vowel 3 /ɛ/; Vowel 10 /a/; Vowel 12 /ə/; Vowel 1 /i/; Vowel 6 /u/

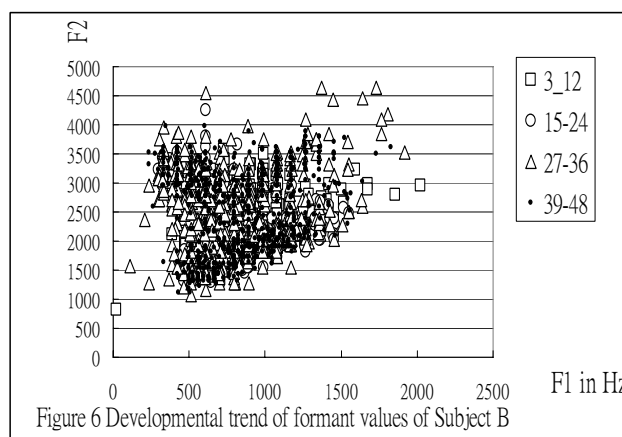
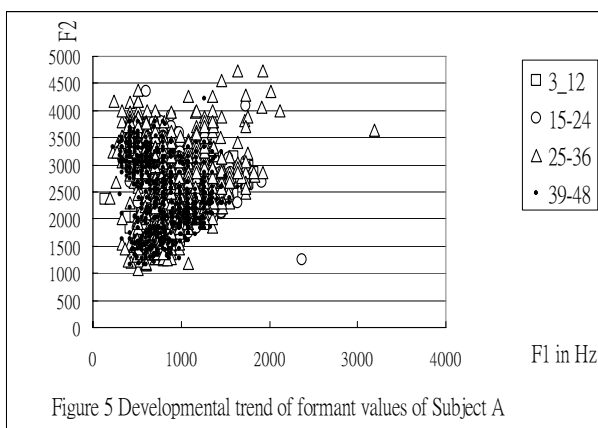
Diphthongs show the highest frequency at this stage and almost all of the diphthongs in Mandarin are found. This development indicates that children at this stage have acquired better speech motor control and timing control in moving from the position of one vowel to the other for producing diphthongs. Both diphthongs with on-glide (e.g., /ia, ua/) and with off-glide (e.g., /ai, au/) appear in both subjects' production. However, /e, o/ are still rarely found probably due to the influence from the input of Taiwanese Mandarin.

In addition, vowels with nasal endings and triphthongs appear. In Subject B, vowels with nasal endings are prominent and display similar frequency of occurrence as single vowels. These vowels are for example, /an, ən, uan, iaŋ/. While in Subject A, vowels with nasal endings are relatively less frequently found. Triphthong /iau/ was found in the third year and is prominent (among the top two frequently used vowels) in the first half of the fourth year in Subject A. However, it is less prominent (3.06%) by the end of the fourth year. For Subject B, this vowel starts to be used frequently from 3 years and 9 months and shows the highest frequency of occurrence (12.92%) among all the vowel categories by the end of the fourth year.



CHANGES OF FORMANT FREQUENCIES

Like what was found in Perry, Ohde, & Ashmead (2001) and Whiteside & Hodgson (2000), from 42 months on, 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. The differences are found in the average values for all the vowels and are also prominent in the development of /a/ and /ə/. In Subject A, the average values of F1 decrease from 756Hz to 721Hz and F2 from 2562Hz to 2425Hz from the third to the fourth year, while no tendency of decrease in formant values is found in Subject B (on the contrary, increase of formant frequencies is observed). Regarding the developmental trend of the four stages in the fourth year, an obvious decrease of formant frequencies is found starting from 3 years and 6 months for Subject A (F1 average values: decrease from 764Hz (3;3) to 710Hz (3;6) to 702Hz (3;9); F2 average values: decrease from 2564Hz (3;3) to 2190Hz (3;6)).



Diphthongs and /ɪaʊ/ are used frequently at this stage, and some clear formant transitions are observed. However, in most of the cases, the vowel transition is still not found to be clearer than the previous stage.

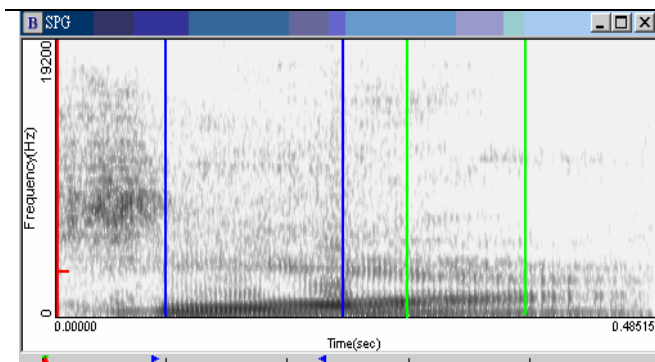


Figure 7 /ia/ produced by Subject A at 3 years and 2 months

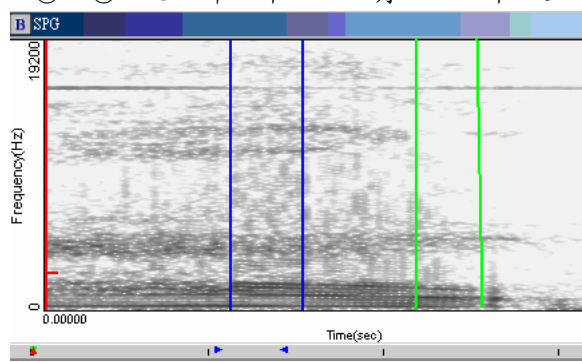


Figure 8 /au/ produced by Subject B at 3 years and 3 months

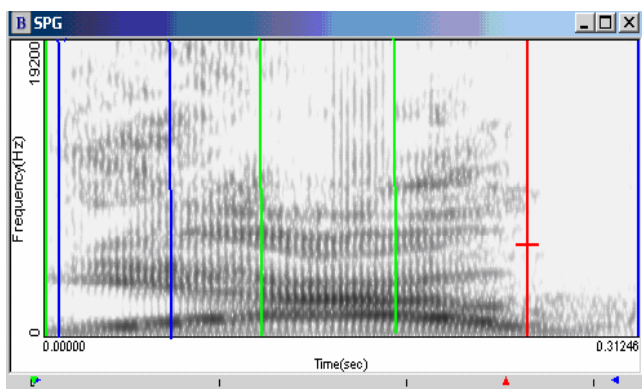


Figure 9 /ia/ produced by Subject A at 3 years and 9 months

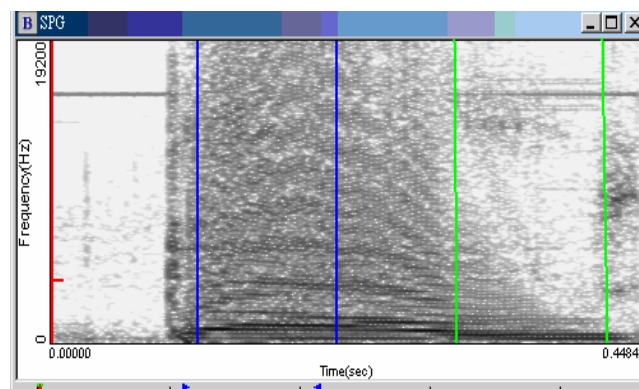


Figure 10 /au/ produced by Subject B at 3 years and 9 months

IV. CONCLUSION

The vowel production in two Mandarin-learning children was recorded in a longitudinal study from birth to 48 months. Major findings in the fourth year of development are: 1) Except for /y/, almost all of the single vowels (including corner vowels) in Mandarin appear and they are evenly distributed; 2) Diphthongs appear more frequently than single vowels, and almost all of the diphthongs in Mandarin are found at this stage; 3) In the girl subject, vowels with nasal endings are prominent and display similar frequency of occurrence as single vowels; 4) Triphthong /iau/ are frequently produced by both children in this stage; 5) The girl subjects seem to develop earlier than the boy subject in several aspects: less rely on the early-acquired /a/, produces more new vowel categories (vowels with nasal endings and diphthongs); 6) From 42 months on, the boy subject shows lower vowel formant values, reflecting gender differences in the development of vocal tract. Gender differences in vowel development found in this study should be verified in further studies.

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