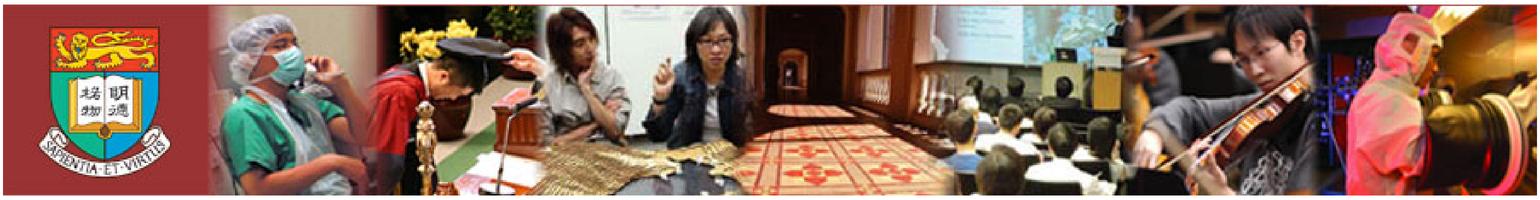

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Vowel and diphthong development in Cantonese-speaking children aged 10 to 27 months

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Abstract

This study addresses the principle of markedness and its relation to single vowel and diphthong development. Spontaneous speech samples were collected from 40 Cantonese-speaking children aged between 10 and 27 months. The samples were analyzed to determine the phonetic and phonemic inventories of Cantonese single vowels and diphthongs. The phonetic development of vowels and diphthongs generally follows the markedness principle while the phonemic data reflect an influence of the ambient language. [labial], [high], [dorsal] and [lax] are found to be the marked features in Cantonese. The results suggested a hierarchy of vowel feature development with decreasing order of height > backness > roundness. Diphthongs with round and dorsal elements appeared in the later stages of development. Both motoric and linguistic explanations account for the results.

Introduction

In the field of child phonology, large bodies of research have been devoted to the investigation of the normal course of development and the hierarchy of feature acquisition of consonants. On the contrary, there have been few studies of vowel and diphthong development. Little attention has been paid to vowel development perhaps because vowels are considered to be acquired easily, rarely misarticulated (Stoel-Gammon and Herrington, 1990) and of little theoretical implication (Davis and MacNeilage, 1990). However, these assumptions should be revised.

Davis and MacNeilage (1990) pointed out that vowels are not easy to learn. Paschall (1983) reported that the mean accuracy of vowel production of 20 children aged 16 to18 months was below 60%. Otomo and Stoel-Gammon (1992) found that the mean percentage of correct production of unrounded vowels for children aged 26 months was merely 63.5%. Further, children with communication disorders also had difficulties in producing single vowels and diphthongs. Pollock and Keiser (1990) examined the vowel errors produced by 15 phonologically disordered children. Results showed that half of the subjects produced vowels with less than 80% accuracy and 14 of the subjects produced errors on diphthongs. The case studies reported by Stoel-Gammon and Herrington (1990) also showed that various vowel and diphthong errors were prominent in two phonologically disordered children. Pollock and Hall (1991) examined the vowel misarticulations of five children with apraxia of speech. Most of the children exhibited difficulties with diphthongs and the tense/lax contrast, and backing of vowel production was also frequently noted. Therefore, vowels and diphthongs are not as easy to acquire as previously claimed.

Indeed, vowels and diphthongs do play an important role in phonology. They are of theoretical interest and should attract research efforts Lindau, Norlin and Svantesson (1985) found that diphthongs occur in approximately one third of the world's languages. Ling (1989) stated that diphthongs frequently occur in children's early words. Research has shown that consonant-vowel interactions are present in early phonological development (e.g. Stoel-Gammon, 1983; Davis and MacNeilage, 1990; Tyler, 1996). Therefore, investigation of vowel and diphthong development is essential for a thorough understanding of phonological development.

Further, studies of vowels and diphthongs may provide additional insights to the issue of universal patterns of development. According to generative phonology, it is suggested that children acquire unmarked features before marked ones and a phoneme with least featural complexity (least marked features) would be acquired first (Ingram, 1997). Jakobson (1968/1941) made a strong assumption about the universal pattern of vowel acquisition based on markedness and maximal contrast. He predicted that children would acquire the less marked vowels with maximal contrast first, that is, [a] and [i]. Then, the marked round vowels would be acquired at the latest stage of development because the secondary rounded vowels are developed only on the basis of primary unrounded vowel development. As these patterns are considered to be universal, it is hypothesized that Cantonese-speaking children would also acquire vowels based on the markedness principle, with the least marked vowels developing first. For diphthongs, an hypothesis is made based on Ingram's (1997) suggestion that diphthongs with least featural complexity (i.e., least difference between the two constituent vowels) will be acquired first. It is assumed that children have to "mark" the difference between the two constituent diphthong vowels in their underlying representation. Therefore, the greater the difference between the features of the vowels in a diphthong, the greater will be the featural complexity, and thus, the later the acquisition.

The purpose of the present study is to investigate whether or not vowel and diphthong development, including error patterns, reflects markedness principles as suggested by Ingram (1997) and Jakobson (1968/1941).

First, previous literature on vowel and diphthong development is reviewed.

Literature Review

Single vowels. Some studies of vowel development focus on the context of accuracy of production while others are concerned with phonetic inventories. Irwin and Wong (1983) together with colleagues conducted a series of studies to investigate the phonological development of children aged 16 to 72 months. In Irwin and Wong's (1983) book, Paschall (1983) reported that twenty American English-speaking children aged 16 to 18 months produced the vowels /a, ʊ, ɪ, ʌ, i / with 73% to 81% accuracy, and the mid and r-coloured vowels were produced with least accuracy. Selby, Robb and Gilbert (2000) studied the phonetic development of English-speaking children aged 15 to 36 months. The lax vowels / ɪ, ʊ, ʌ / were produced by the youngest subjects. Then, the corner tense vowels /a, u, i/ were acquired in their subjects at 18 months of age. Beers (1995) collected data from Dutch speaking children, and found that the corner vowels [i], [a] and [u] were mastered first. In addition, she reported that tense vowels and rounded vowels were acquired after their lax and non-rounded counterparts. For Cantonese, Tse (1991) investigated the vowel development of a child from 14 to 36 months. He indicated that the maximally contrasted vowels /i/ and /a/ were acquired first. Besides, he suggested that unrounded vowels were developed before rounded vowels [œ] and [y]. Further, the lax vowel [ɐ] was developed after the conjugate tense vowel [a].

From previous studies, consensus was found in terms of the early mastery of maximally contrasting vowels, [i] and [a] and the unrounded vowels. This finding was consistent with Jakobson's (1968/1941) prediction. Actually, apart from Jakobson, Beers (1995) has also predicted vowel development on the basis of segmental complexity and markedness. However, her prediction could not be fully confirmed by her data. She expected that /ɪ/ and /ʌ/ would be acquired first. Yet, the vowel /ʌ/ was acquired after the comparatively more marked and segmentally more complex vowels [u], [ɛ], [a]. Further, she assumed that [tense] is a marked feature. Some of the tense vowels were mastered after their lax counterparts. However, her assumption of tense after lax could not be confirmed because both tense and lax vowels [i] and [ɪ] were mastered at the same age. Secondly, the tense vowel [a] was acquired before its lax counterpart. Furthermore, whether the tense or lax vowels are acquired first has not been clearly displayed from English data. In addition, a previous study on Cantonese (Tse, 1991) suggested that children acquired tense vowels before their lax counterparts. Therefore, [tense] is assumed to be a default in this study. Here, the acquisition pattern of vowels in Cantonese-speaking children will be described in terms of the markedness principle.

Diphthongs. To date, research concerning vowel development has focused on single vowels and only a few studies have paid attention to diphthongs. The research done by Wellman and colleagues (as cited in Ferguson and Stoel-Gammon, 1992) provides information about both vowel and diphthong development. From 204 children aged between 2;0 and 6;0, it was reported that children mastered the diphthongs /ai/, /ɔi/ and /au/ by age 3;0 and the vowels /ɪ, e, ae, ʊ/ appeared at age 4;0. Though only three diphthongs were mentioned in this study, results revealed that some diphthongs are acquired before the mastery of all the pure vowels in the English sound system. On the other hand, the study by Paschall (1983) also shed some light on English diphthong development. Paschall (1983) reported that twenty children aged 16-18 months produced the diphthongs /au, ɔi/ and /ai, iu/ with accuracy ranging from 60% to 62% and 40% to 47% respectively. Hare's (1983) 21-24 month-old subjects produced the diphthongs /au, ɔi, ai, iu/ with over 97% accuracy. Comparing the studies by Paschall and Hare (1983), it is suggested that there is a remarkable improvement in diphthongs acquisition by age 2;0 and children master the diphthongs /au ɔi ai iu/ by 2;0. However, only four diphthongs have been investigated, limited data precludes the establishment of a clear profile for diphthong development.

With regard to Cantonese, Cheung (1990) examined the acquisition of Cantonese phonology by collecting cross-sectional data from 155 children aged between 2;1 and 6;0. By setting 90% of correct production as the mastery criterion, Cheung (1990) found that children mastered most of the vowels /i, y, u, ɔ, a, ɐ/ by age 2;0 and the remaining vowels (/ɛ/ and /œ/) by 2;6 and 3;0 respectively. She also reported that children acquire the diphthongs /ui/, /ei/,/ɔi/ /ɐi/, /œy/, /iu/, /ou/ and /ɐu/ by age 2;0; /au/ by 2;6 and /ai/ by 3;0. By looking into the data, it seems that some diphthongs appeared before the mastery of some single vowels and this is consistent with the data reported by Wellman et al. (1931). Besides, it is interesting to find that children acquired /œy/ by 2;0 but the pure vowel /œ/ is not mastered until 3;0. Cheung's (1990) study provides some insight about diphthong development in Cantonese. However, the youngest group of subjects in her study was 2;0. Her study only reported that the diphthongs /ui/, /ei/, /ɔi/ /ɐi/, /œy/, /iu/, /ou/ and /ɐu/ were all mastered by age 2. Does it suggest that there is a spurt of diphthong development at age 2;0 or that children actually acquire these diphthongs before 2;0? Further, the pattern of diphthong acquisition has not been formally established and no proposal has been suggested to predict diphthong development. In this research, diphthong development will be studied in children from 10 to 27 months of age and the principle of markedness will be addressed to predict the diphthong development.

The Features System of Cantonese

Single vowels. According to Zee (1998 and 1999), there are seven long vowels (a, i, ε, ɔ, u, œ, y) and four short vowels (ɪ, θ, ɐ, ʊ) in Cantonese. Among the long vowels, the vowels /a, i, ε, ɔ, u/ are regarded as primary vowels while the rounded vowels /œ, y/ are labeled as secondary vowels (Tse, 1991). Of the four short vowels, /ɪ/, /θ/ and /ʊ/are actually allophones of /i/, /œ/ and /u/ respectively. Therefore, there are primarily eight contrastive vowels in Cantonese. Using a multivalued feature system, vowels can be classified in terms of (1) height, (2) backness, (3) tenseness and (4) roundness. According to Zee (1998), three levels of height can be distinguished in Cantonese. /i, u, y/ are designated as high vowels; /œ, ε, ɔ/ as mid vowels and /ɐ, a/ as low vowels. For the front-back dimension, /i, ε, y/ are defined as coronal vowels and /ɔ, u/ as dorsal vowels (Zee, 1999). Further, Zee (1998) suggested that /œ/, /ɐ/ and /a/ are central vowels in Cantonese. In terms of features, Clement and Hume (1995) suggested that central vowels should be designated as *placeless*. For tenseness, there are seven tense vowels and one lax vowel [ɐ] in Cantonese. Finally, /ɔ, u, y, œ / are further designated as rounded vowels with the feature [labial]. The classification of Cantonese vowels is displayed in Figure 1.

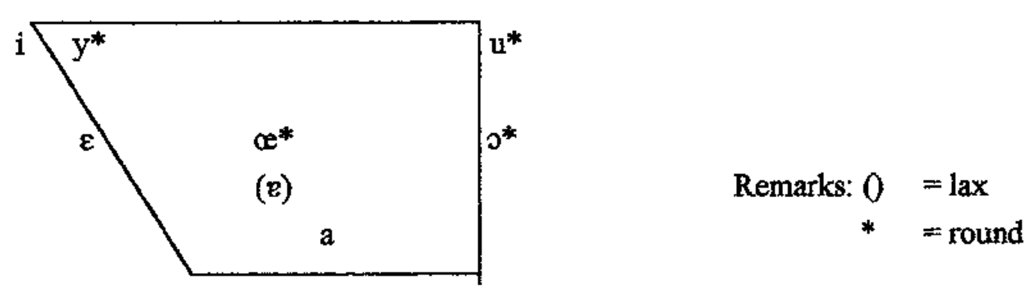

Figure 1. Classification of Cantonese vowels.

Further, a radical underspecification approach was adopted to present the vowel features in the present study. In the radical underspecification approach, only the marked features are specified. The level of featural complexity of each vowel is coded by summing the marked features (adopted from Chomsky & Halle, 1968). The marked features and the level of complexity of each vowel are summarized in Table 1. The vowels are coded as 0-feature, 1-feature, 2-feature or 3-feature vowels in the following discussion.

Table 1

Feature System of Cantonese Vowels

	a	ɛ	ɐ	i	œ	y	ɔ	u
Height				[high]		[high]		[high]
Backness							[dorsal]	[dorsal]
Roundness					[labial]	[labial]	[labial]	[labial]
Tenseness			[lax]					
Level of featural complexity	0	0	1	1	1	2	2	3

Diphthongs. Diphthongs are regarded as a sequence of two vowels within the nucleus (Bernhardt & Stemberger, 1998). Bernhardt (1992) suggested that diphthongs have two Root nodes (VV). According to Zee (1999), it is generally accepted that there are 10 diphthongs in Cantonese, including /ei/, /ai/, /iu/, /ui/, /au/, /ou/, /ɐi/, /ɐu/, /ɔi/and /œy/. Another diphthong (/ɛu/) only occurs in a limited number of words (Zee, 1999), therefore, it was not included in this study.

Based on the assumption mentioned above, a system of featural complexity was also adopted for the study of diphthongs, with only the conjugate features marked in the system.

For example, the feature complexity of /ai/ is 2 since only the feature differences in height ([-high] vs [+high] and [+low] vs [-low]) were marked. The feature difference in place was not marked. This is because as previously defined, the central vowel is placeless, therefore, there was no conjugate feature of [coronal] in /a/.

a	i
[-high]	***[+high]***
[+low]	***[-low]***
	[coronal]
[-labial]	[-labial]
[tense]	[tense]

By working in this way, the level of featural complexity of each diphthong was determined as shown in Table 2. A full specification of the features for each diphthong is presented in Appendix A. The diphthongs are coded as 1-feature, 2-feature, 3-feature or 4-feature in the following discussion.

Table 2

Level of Featural Complexity of Cantonese Diphthongs

Diphthong	Level of featural complexity	Diphthong	Level of featural complexity
ei	1	ɔi	3
œy	1	au	3
ou	1	ɐi	3
ai	2	ɐu	4
ui	2		
iu	2		

In this study, it is hypothesized that children would acquire Cantonese vowels and diphthongs based on the markedness principle, with the less complex vowels and diphthongs develop before those with higher featural complexity.

Method

Subjects

A total of 40 Cantonese-speaking children, 10 in each of the following age groups: 10-13 months (Group I), 15-18 months (Group II), 20-23 months (Group III) and 24-27 months (Group IV), participated in this study (see Table 3). All the subjects were recruited from the relatives and friends of students studying at the University of Hong Kong.

Normal development was established based on parental declaration of normal developmental history. All subjects had no known gross neurological, visual, hearing or organic deficits as determined by developmental screening conducted by the Maternal and Child Health Centre.

Table 3

Subjects' Information

Age Group	Sex	Mean Age
I: 10-13 months	3 Males ; 7 Females	11.6 months
II: 15-18 months	3 Males ; 7 Females	16.2 months
III: 20-23 months	5 Males ; 5 Females	21.6 months
IV: 24-27 months	5 Males ; 7 Females	25.2 months

Data Collection

Audio-recordings were carried out at the children's homes. Each subject was recorded individually. For each sampling session, the subject interacted with the caregivers and/or the investigator for approximately one hour. Various toys and picture books were used to elicit the child's vocalization during free play. Selection of toys was not standardized across each subject.

Four portable minidisc recorders (Sony MZ-R50 and Sharp MD-MT821W) and portable microphones (Aiwa CM-TS22) were used to record the children's speech. A microphone was clipped on the subject's clothing at the chest level, within a distance of 15 cm from the subject's mouth, throughout the session.

Data Analysis

Four experienced transcribers independently transcribed 100 vocalizations, including all the meaningful speech and babbling output produced by each child. The broad form of the International Phonetic Association symbols was used for transcription.

Babbling output was included because Selby et al. (2000) suggested that by considering the subjects' glossable and non-glossable productions in their analysis, more diverse vowel inventories were documented. In addition, an investigation by Davis and MacNeilage (1990) on vowel development suggested that the vowels produced by a child in babbling output was not necessarily favoured in early meaningful words. Therefore, non-glossable babbling output was also included in the current analysis as it was expected that a more comprehensive profile of phonetic proficiency would be documented.

Besides, no attempt was made to exclude imitated vocalizations from spontaneous production, as Ferguson and Farwell (1975) and Selby et al. (2000) suggested this procedure did not cause significant differences in the types and tokens of the sounds produced by typically-developing children.

Phonetic inventories. The phonetic transcriptions were analyzed to establish the phonetic and phonological developmental profiles of Cantonese vowels. For the analysis of phonetic proficiency, vowels that occurred in babbling output and early words were both taken into consideration. When 70% of the children of an age group (7 out of 10 subjects) produced a vowel with more than one occurrence, the vowel was considered present in the group data (adopted from Selby et al., 2000).

Phonemic inventories. For phonological competence, only the data collected from the subjects aged 15 to 27 months were included because most of the youngest group of subjects (10-13 months) did not produce any real words. In the analysis, only the child's real words were analyzed, while sentence final particles, interjections and English attempts were all excluded. For each subject, the percentage correct realization of every target vowel was calculated. Then the mean percentage of accuracy for a target vowel across an age group was derived.

A Frequency Criterion (FC) was adopted to interpret whether the vowels were acquired or just emerging (Beers, 1995). A vowel was considered *acquired* when the following criteria were fulfilled: (1) the mean percentage of accuracy was equal to or larger than 75% in an age group; (2) at least 5 subjects of the age group had to attain 75% accuracy in more than one attempt of the target sound. On the other hand, a vowel was regarded as *emerging* when the mean percentage of correct realization lay between 50% and 74%.

Further, the subjects' realizations of every target vowel were delineated and the prominent error patterns of each vowel were identified.

Reliability

For establishing both inter- and intra-judge reliability of the transcriptions, the percent of agreement of transcriptions both within a transcriber and between the four transcribers was determined by randomly choosing 10% of the recorded samples for point-by-point comparison. The intra-judge and inter-judge reliability ranged from 82% to 90%

and 85% to 88% respectively across four transcribers. Using the method suggested by Stoel-Gammon and Herrington (1990), problems of disagreement on transcription were resolved by transcribers listening to the questionable item together and compromising on the final version.

Results

Single Vowel Development

Phonetic inventories. The group phonetic inventories are shown in Table 4. The group inventories show those vowels that were produced with more than one occurrence by more than 7 subjects in each age group. Across the 10-27 months of age, the vowel types increased from five to eight. The phonetic inventory of Cantonese vowels is completed by the age of 20-23 months.

At the earliest age period (10-13 months), the children primarily produced the least complex vowels [a, ɛ] and all the 1-feature vowels [i, œ, ɐ]. By 15-18 months, a 2-feature vowel [ɔ] and a 3-feature vowel [u] were added. Finally, another 2-feature vowel [y] was present at 20-23 months of age.

The results can also be presented in terms of feature development. First, the coronal and placeless vowels [a, ɛ, i, œ, ɐ] were produced. Early occurrence of the high vowel [i] suggests that children have already developed the height distinction ([i] versus [a]). Besides, the tense/lax contrast had also developed as is evident from the acquisition of [a] and [ɐ]. At this age period, a rounded vowel [œ] emerged, but no dorsal vowel was noted. At 15-18 months of age, two dorsal vowels [u, ɔ] were added. The contrastive production of [u] versus [i] and [ɛ] versus [ɔ] suggests that the children had acquired the front-back distinction. At the 20-23 months of age, the production of the coronal round vowel [y] shows the round and non-round distinction.

Table 4

Group Phonetic Inventories of Single Vowel

Age Group	Phonetic Inventory				Feature Acquired
	0-feature	1-feature	2-feature	3-feature	
10-13 months	a, ɛ	i , œ, ɐ			High/low distinction Tense/lax distinction
15-18 months	a, ɛ	i , œ, ɐ	ɔ	u	Coronal/dorsal distinction
20-23 months	a, ɛ	i , œ, ɐ	ɔ, y	u	Rounded/unrounded distinction
24-27 months	a, ɛ	i , œ, ɐ	ɔ, y	u	---

Phonemic inventories. Figure 2 displays the accuracy of vowel realization in the subjects' glossable utterances. The individual's accuracy of vowel realization is shown in Appendix B. As mentioned before, the mean percentage of correct realization had to be equal to or larger than 75% to be included as *mastered* vowels. On the other hand, a vowel was regarded as *emerging* when the mean percentage of correct realization lay between 50% and 74%. Given the above criterion, the group phonemic inventories of Cantonese vowels is shown in Table 5. The children had not mastered any vowel at 15-18 months, but the vowels [a, ɛ, i, ɔ] had emerged. At 20-23 months of age, [a], the vowel with least feature complexity; and a 2-feature vowel [ɔ] had developed. At 24-27 months, another least complex vowel [ɛ], two 1-feature vowels [i] and [ɐ], and a 2-feature vowel [ɔ] were further mastered with other vowels [œ, u, y] only emerging.

In terms of features, it is noteworthy that a mid vowel [ɔ] and a low vowel [a] were mastered at the earliest stage, reflecting a height distinction. At 24-27 months of age, the children were also able to distinguish the duration of vowels by adding the lax counterparts of [a]. In addition, the mastery of [ε] versus [ɔ] reflects coronal/dorsal distinction. However, the phonemic inventory was not complete at 24-27 months, as most of the rounded vowels had not been mastered. The feature [labial] was not considered as fully developed as the children did not show the contrastive realization of [i] and [y].

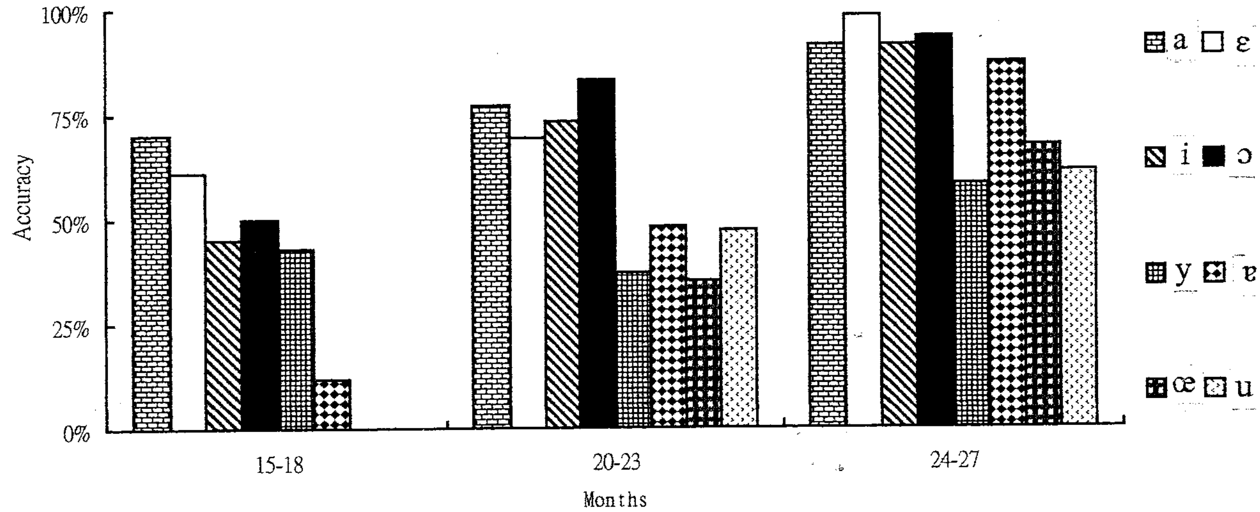

Figure 2. Accuracy of single vowel production

Table 5

Group Phonemic Inventories of Single Vowels

Age Group (months)	Emerging vowel 0-feature	1-feature	2-feature	3-feature	Mastered vowel 0-feature	1-feature	2-feature	3-feature	Feature Acquired
15-18	a, ε	i	ɔ						---
20-23	ε	i			a		ɔ		Height distinction
24-27		œ	y	u	a, ε	i, ɐ	ɔ		Coronal/dorsal distinction Tense/lax distinction

Error patterns. The vowel errors produced by the subjects are summarized in a confusion matrix (see Appendix C). The prominent vowel error patterns are presented in Table 6. Among the prominent error patterns, it was found that target vowels mostly surfaced as placeless vowels [a, ə, ɐ]. The high vowels were realized as mid vowels [ɛ, ɔ]. Most of the rounded vowels / ɔ, œ, y/ were realized as unrounded vowels [a, i]. Tense/lax confusion was shown by the inter-substitution of [a] and [ɐ]. For other tense vowels, the [tense] feature was always maintained.

Table 6

Prominent Error Patterns on Single Vowel Production

Target	Subjects' Realization	Alteration	Maintenance
a	ɐ	tense → lax	Place, height
ɐ	a	lax → tense	Place, height
i	ɛ	high→ non-high	Place, tenseness
u	ɔ	high → non-high	Place, tenseness
ɛ	ə	coronal → placeless tense → lax	Height
œ	a	Rounded → unrounded Non-low→ low	Place, tenseness
y	i	Rounded→ unrounded	Place, height, tenseness
ɔ	a	Rounded → unrounded dorsal→ placeless non-low→ low	tenseness

Diphthong Development

Phonetic inventories. Table 7 shows the group phonetic inventories of diphthongs. Across 10-27 months of age, the size of the phonetic inventory of diphthongs increased from one to nine. At the earliest age period, the children articulated the least complex diphthong [ei]. At 15-18 months of age, a 2-feature diphthong [ai] was added. By 20-23 months, the number of diphthongs increased to five, in which 1-feature [œy, ou] and 2-feature diphthongs [iu] were further developed. In addition, a 3-feature diphthong [ɐi] was added. At 24-27 months of age, the number of diphthongs dramatically increased from five to nine. The 2-feature diphthong [ai] re-occurred, other 3-feature diphthongs [ɔi, au] and the most complex 4-feature diphthong [ɐu] appeared. At this stage, children produced most of the Cantonese diphthongs, but the 2-feature diphthong [ui] was absent from the phonetic repertoire.

Table 7

Group Phonetic Inventories of Diphthongs

	Phonetic Inventories				
Age Group	1-feature	2-feature	3-feature	4-feature	Size
10-13 months	ei				1
15-18 months	ei	ai			2
20-23 months	ei, ou, œy	iu	ɐi		5
24-27 months	ei, ou, œy	ai, iu	ɐi, au, ɔi	ɐu	9

Phonemic inventories. The individual's accuracy of diphthong realization is shown in Appendix D. Figure 3 shows the accuracy of diphthong production for the three oldest groups of subjects. The figure illustrates a steady increase in diphthong accuracy as well as an increase in inventory size. Table 8 displays the group phonemic inventories of Cantonese diphthongs derived from the children's glossable utterances. By using the same frequency criterion adopted for vowel development, it was found that no diphthong was either mastered or emerged at 15-18 months. By 20-23 months of age, two 1-feature diphthongs [ei, ou] were emerging. At the age of 24-27 months, the 1-feature diphthong [ou] and a 3-feature diphthong [ɐi] were mastered. Another 1-feature diphthong [ei], 2-feature diphthongs [ai, iu], 3-feature diphthongs [au, ɔi] and the 4-feature diphthong [ɐu] were emerging. However, it should be noticed that the 2-feature diphthong [ei] and 3-feature diphthong [au] nearly met the criterion level of mastery. On the other hand, the 1-feature diphthong [œy] and 2-feature diphthong [ui] were still excluded from the phonemic repertoire at 24-27 months of age.

Table 8

Group Phonemic Inventories of Cantonese Diphthongs

	Phonemic Inventories			
Age Group	1-feature	2-feature	3-feature	4-feature
15-18 months				
20-23 months	ei, ou			
24-27 months	ei, ou*	ai, iu	ɐi* , ɔi, au	ɐu

Note. The mastered diphthongs are marked with an asterisk.

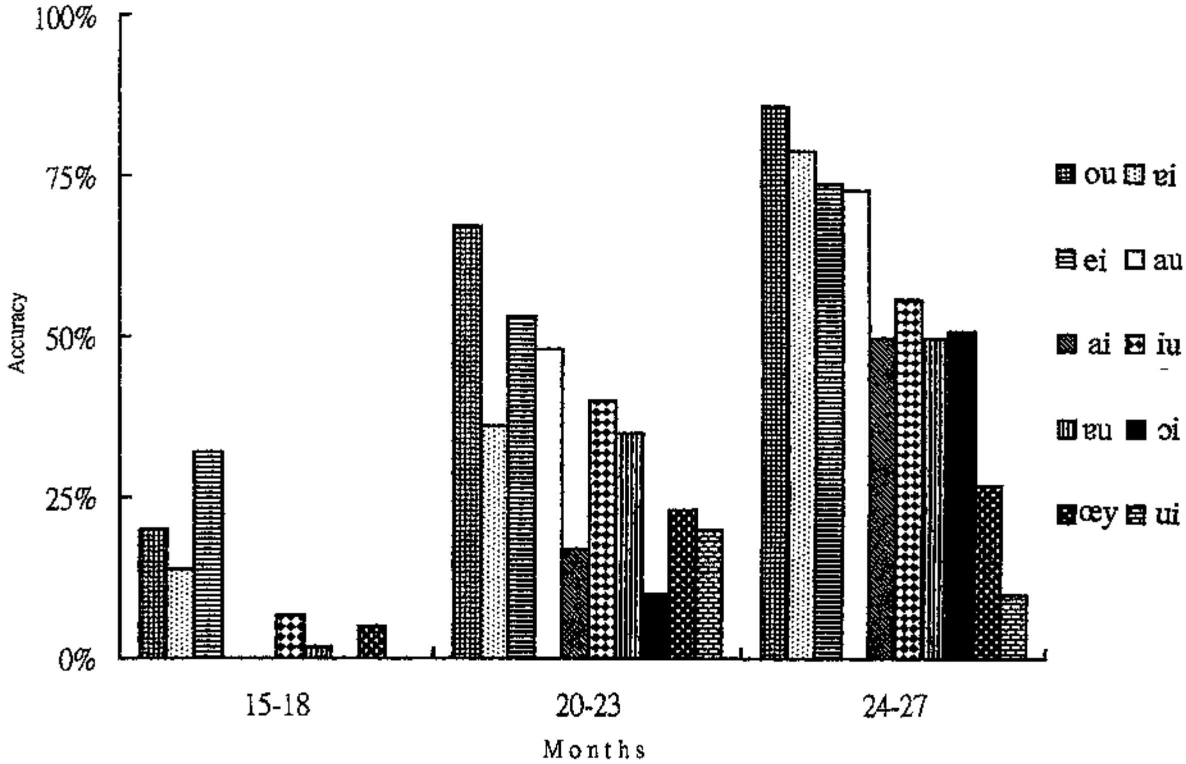

Figure 3. Accuracy of diphthong production

Error patterns. The errors noted in diphthong production are summarized in a confusion matrix (see Appendix E). The prominent error patterns are listed in Table 9. Prominent error patterns that were only contributed by one subject were excluded, as they may not be representative of the sample. The most prominent error pattern was final vowel deletion, and only the diphthong /ɐi/ was realized by a less complex diphthong [ei]. For final vowel deletion, it is noticed that the first element of the diphthong was always maintained while the second element was deleted. For the most complex diphthong, /ɐu/, not only the final vowel was deleted but the tenseness of the first element was altered, and [a] resulted.

Table 9

The Prominent Error Patterns on Diphthong Production

Target	Subjects' Realization	Alteration
ɐi	ei	Level of featural complexity reduced
ei	ɛ	Final vowel deleted
ɔu	ɔ	Final vowel deleted
ɐu	a	Final vowel deleted, tensed
œy	œ	Final vowel deleted
ai	a	Final vowel deleted
iu	i	Final vowel deleted
ui	ɛ[1]	Final vowel deleted, centralized
ɔi	ɔ/a[2]	Final vowel deleted
au	a	Final vowel deleted

Note. 1 67 7% of the realizations of [ɛ] was produced by only one subject

2. [a] and [ɔ] take the same proportion of realization for the target diphthong [ɔi]. Yet, all the [a] realizations were produced by the same subject.

Discussion

Featural Complexity and Vowel Development

The phonetic data in the present study confirm the prediction on vowel development based on the markedness principle. Results shown that children articulated the least complex vowel at the earlier developmental stage. The 0-feature and 1-feature vowels were produced by the youngest group of subjects. In addition, the more complex, 2-feature and 3-feature vowels were produced at a later stage. The prominent error patterns further support the hypothesis. Children tended to substitute the target vowel with a less complex vowel. The more marked rounded vowels mostly surfaced as less marked unrounded vowels and some of target vowels were realized as the least complex vowel [a]. The notion of substitution towards the least complex vowel [a] suggests that [a] is a default vowel. Consistent information was reported from previous studies. Paschall (1983) reported that the vowels /æ, ɔ/ were most frequently substituted by the vowel [a]. Stoel-Gammon et al. (1990) described the errors produced by two phonologically disordered children. Four target vowels surfaced as [a]. Further, Stankiewicz (1972) reported that his subject realized the target vowels /ɛ/ and /ɒ/ as [a] (as cited in Reynolds, 1990). The recognized default can also be explained on articulatory basis. According to the Frame/Content model, Frame denotes an articulatory event of regular open and close oscillation of the mandible, which is dominant at early age (Davis et al., 1995). Since the production of /a/ does not involve any tongue movement, the "pure dynamic frame" (Davis et al., 1990) results in the low-to-mid front-to-central vowel production. Thus, the vowel [a] was produced by default.

Based on the markedness prediction, the 3-feature vowel is the latest to be produced. Yet, it is noticed that children articulated the 3-feature vowel [u] before one of the 2-feature vowels, [y]. [y] was not articulated before [u] because children would not be able to differentiate [i] vs [y] without a basis of differentiation of the primary vowels [i] and [u] (Beers, 1995). The finding is supported by Tse's (1991) data. This further lends support to Jakobson's (1968/1941) prediction that front rounded vowels would not occur before unrounded vowels.

Unmarked / Marked Features in Cantonese

Indeed, the late mastery of [y] and the error pattern noted from the rounded vowels further confirm [labial] as a marked feature during development. Besides, the present data also confirm that [tense] is an unmarked feature in Cantonese. From the phonemic data, tense vowels were developed first at 20-23 months and the lax vowel was mastered by 24-27 months. In addition, children were able to maintain the [tense] feature for most of the target vowels, while the target lax vowel [ɐ] was realized as a tense vowel [a]. Therefore, it is suggested that [lax] is a marked feature. This finding is also supported by other studies. Tse (1991) found that his subject acquired the tense vowels [ɛ, a, i] at an earlier age and the lax vowel [ɐ] was not mastered until 26 months. Stoel-Gammon (1991) suggested that lax vowels are less frequent and more difficult to produce than tense vowels Thus, tense vowels [u] and [i] were included in early mastery but their lax counterparts [ʊ] and [ɪ] were found in the mid and late mastery categories.

In addition to [labial] and [lax] being regarded as marked features, results further reflect that [high] and [dorsal] are marked features in Cantonese. In phonemic development, the high vowel [i] was acquired after the mastery of mid vowel [ɔ] and low vowel [a] and the error pattern reflected that the high vowels always surfaced as mid vowels. In the front-back dimension, results suggest that [dorsal] is a marked feature in development. Evidence is shown from the phonetic data, in which only placeless and coronal vowels were produced in the earliest age period. This finding is supported by Bhur's study (1980). He claimed that " the musculature of the lips, jaw, and frontal portion of the tongue seem to develop at a faster rate than the lowering of the larynx and rear portion of the tongue" (p. 91). Therefore, [dorsal] is probably marked during development.

Apart from the markedness reflection attained from the phonetic data, the combined results of phonemic and phonetic data additionally suggest a hierarchy of vowel feature development. Besides, an influence of ambient language on vowel development was also noted.

Hierarchy of Feature Development

Height. Based on the phonetic and phonemic results, it is worth noting that the height feature was specified first. The phonetic and phonemic distinction of height was noted at 10-13 months and 20-23 months respectively. This finding is supported by Tse's (1991) data. His subject also made a specification on the height distinction in the first place as shown by the acquisition of the low vowel, [a] and high vowel, [i] at 14-15 months. Consistent findings were also reported in English data. Bernhardt and Stemberger (1998) commented that the height distinction is developed first in English-speaking children. The result can also be interpreted from the view of "Frame Dominance", as MacNeilage, Davis and Matyear (1997) suggested, changes in height dimension could be easily attained by the mandibular movement. Therefore, height distinction is firstly specified.

Backness. The front/back distinction is specified after the specification of the height contrast. The coronal and dorsal distinction was noted at 15-18 months in phonetic development while the phonemic distinction of coronal and dorsal developed by 24-27 months of age. This finding is supported by Tse's data. Tse (1991) reported that his subject had acquired the low [a] and high vowel [i] at the period of 14-15 months. Yet, the dorsal counterpart of [i], the vowel [u] was not acquired until 23 months. As mentioned before, the rear portion of the oral cavity develops at a slower rate (Bhur, 1980), therefore, it is reasonable that the coronal and dorsal contrast develops at a later stage.

Tenseness. In the phonetic data, children learned both height and tense/lax distinction at 10-13 months of age. On the other hand, the phonemic data suggest that children developed both the front-back distinction and the tense/lax distinction after acquisition of the height contrast. At this stage, whether the tense/lax distinction was specified simultaneously with the height distinction or the front-back distinction is questionable due to the discrepancy between the phonetic and phonemic results.

Roundness. From the phonetic data, the round/non-round contrast developed at the last stage. From the phonemic data, the roundness contrast was not noted even at 24-27 months of age. Therefore, it is suggested that the round-nonround contrast only appears after the height and coronal-dorsal distinctions.

Based on the above discussion, the hierarchy of feature development is summarized in a flow chart as shown in Figure 4.

Height distinction (tense/lax distinction)*

↓

Front-Back distinction (tense/lax distinction)*

↓

Roundness distinction *the timing for tense/lax distinction is uncertain

Figure 4. Hierarchy of feature development in Cantonese vowels

Effects of Ambient Language and Single Vowel Development

Studies on English and Dutch vowel development generally suggest that the corner vowel /i, a, u/ are always mastered early. Yet, the present study together with Tse's (1991) study, noted that the corner vowel [u] was mastered at a later stage. Different acquisition patterns may reflect the influence of the ambient language. Pye, Ingram and List (1987) suggested that, apart from articulatory constraints, the functional load of speech sounds in a language also plays a significant role in determining the order of acquisition in a child's system. Kuhl and Meltzoff (1996) hypothesized that children would store the representation of the target sound to act as a target for production. Therefore, it is expected that the chance for children to compare their production with adult production increases when the frequency of occurrence of that phoneme is high. Hence, children could more readily make changes to their own productions to attain the target sound via continuous practice. The high front vowels are frequent in English (Bernhardt & Stamberger, 1998) so they are acquired first. By contrary, [u] is the least frequent vowel in Cantonese (Fok, 1979). The late mastery of [u] may be attributed to its low frequency of occurrence in the ambient language and thus children have few chances to practice production.

Indeed, the effect of functional load is noted in the phonemic data. The order of vowel acquisition is parallel to the ranked order of frequency of the occurrence of vowels in Cantonese. Cantonese vowels, in the order of decreasing frequency of occurrence (Fok, 1979) are: a > ɔ > i > ɐ > ɛ > œ > y > u

It is found that the most frequently occurring vowel [a] and [ɔ] were mastered in the first stage (15-18 months). Then, the less frequently occurring vowels [i, ɐ, ɛ] were acquired in the second stage (20-23 months). Finally, the least frequently occurring vowels [œ, y, u] were only emerging by 24-27 months.

Featural Complexity and Diphthong Development

From the phonetic data, the trend of diphthong development generally follows the markedness principle. The least complex diphthong [ei] was articulated in the earliest stage of development while the most complex diphthong [ɐu] was produced in the last stage of development. Further, the 2-feature and 3-feature diphthongs were found in the middle stage.

In addition to the observed developmental trend based on the markedness principle, it is suggested that, for the same level of complexity, diphthongs with constituent vowels only differ on the height level would be acquired before those with a difference in either backness or roundness. This pattern is consistent with the hierarchy of feature distinctions noted in single vowel development.

The early occurrence of /ei/ and /ai/ can also be explained in the sense of articulatory basis According to Lindblom (1992), children favour those productions that place least demand on precise temporal and spatial control As mentioned before, Frame denotes the earliest developed regular open-close mandibular movements. For the diphthongs [ei] and [ai], the only difference between the constituent vowels of [e] vs [i] and [a] vs [i] is the level of height Therefore, children can easily attain the sequence of production of [ei] and [ai] by mandibular movement as assumed in the Frame Dominance account (MacNeilage et al , 1997) Actually, the only difference in the constituent vowels of diphthongs [ou] and [œy] is also the level of height but they were present in the later stage. It is suggested that, apart from the "Frame", the production of [ou] and [œy] also involved the "Content" element of the Frame /Content model because the sustained rounding over the two vowels demands good control of the lip position.

Further, among the 2-feature diphthongs, [ai] was produced before [iu]. It is argued that the production of [iu] requires a "Content" element, in which children have to change lip rounding to incorporate transition of the tongue position from coronal to dorsal place sequentially. Further, [ɐi] was the first diphthong to be articulated among the 3-feature diphthongs because the production of [au] and [ɔi] also demand the co-ordination of lip rounding and tongue movement. The 4-feature diphthong [ɐu] developed at the last stage since the constituent vowels in [ɐu] differ on the dimensions of height, roundness and tenseness. In addition to the "Frame", children need a complicated "Content" element for the precise control of roundness and temporal transition during production. Therefore, it is suggested that a diphthong with roundness and dorsal elements may deserve additional marking.

Effects of the Ambient Language and Diphthong Development

The effect of ambient language was also noted in diphthong development. A clear relation was displayed in the phonemic data. The most frequent diphthongs in Cantonese /ɐi, ei, ou, ɐu/ (Fok, 1979) were mastered or nearly achieved the mastery criterion. The less frequent diphthongs, /ai, iu ɔi, au/ were found to be emerging. Finally, the diphthong [ui] with the lowest frequency of occurrence in Cantonese (Fok, 1979) was excluded from the phonemic repertoire. Yet, the exclusion of the diphthong [œy] in the phonemic repertoire cannot be explained in terms of the effect of the ambient language. However, it may be attributed to the last mastery of the constituent vowels [œ] and [y].

Conclusion

The present study found that the phonetic development of Cantonese vowels and diphthongs generally follows the markedness principle. The mastery of vowels and diphthongs was not completed by 24-27 months of age. Data confirmed that [labial], [high], [dorsal] and [lax] are the marked features in Cantonese. A hierarchy of feature development, where the height distinction proceeds the front/back and roundness distinctions was noted. This study suggested that a diphthong with round and dorsal elements would be acquired in the later stages of development. Finally, the effect of the ambient language on vowel and diphthong development was displayed in the phonemic data.

Clinical Implication

A normal developmental trend of Cantonese vowel and diphthong development was provided in this study. The assumption that vowels and diphthongs are easily acquired was proved inaccurate. Therefore, speech assessment should also include the examination of vowel and diphthong productions. The finding, based on the markedness principle, and the additional hierarchy noted in vowel and diphthong development, along with the role of the ambient language could provide insights for clinicians to select appropriate targets for treatment for those children with difficulty in vowel or diphthong production.

Further Research

This study showed that the vowel and diphthong inventory was not completed by 27 months. Further study can recruit older subjects to obtain a complete profile of vowel and diphthong development. Besides, an influence of ambient language on vowel and diphthong development was noted in the present study. Vihman (1996) postulated that the influence of ambient language increases as the size of the lexicon increases Therefore, the relation between the lexicon and vowel/ diphthong development merits further study. Further, this study was limited to the segmental level, the interaction between vowels/diphthongs and consonants deserves further investigation. Finally, as Cantonese is a tonal language, the effect of tone on vowel and diphthong development is worth exploration.

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Appendix A

Table A1

Level of Featural Complexity of Diphthongs

	Contrast		
Diphthong	1st element	2nd element	Level of featural complexity
ei	e	i	
	[-high]	***[+high]***	
	[-low]	[-low]	
	[coronal]	[coronal]	
	[-labial]	[-labial]	
	[tense]	[tense]	1
ou	o	u	
	[-high]	***[+high]***	
	[-low]	[-low]	
	[dorsal]	[dorsal]	
	[+labial]	[+labial]	
	[tense]	[tense]	1
œy	œ	y	
	[-high]	***[+high]***	
	[-low]	[-low]	
		[coronal]	
	[labial]	[labial]	
	[tense]	[tense]	1

Note. The conjugate features are bolded and in italics

(table continues)

Diphthong	Contrast: 1st element	Contrast: 2nd element	Level of featural complexity
ui	u	i	
	[+high]	[+high]	
	[-low]	[-low]	
	[dorsal]	***[coronal]***	
	[+labial]	***[-labial]***	
	[tense]	[tense]	2
iu	i	u	
	[+high]	[+high]	
	[-low]	[-low]	
	[coronal]	***[dorsal]***	
	[-labial]	***[+labial]***	
	[tense]	[tense]	2
ai	a	i	
	[-high]	***[+high]***	
	[+low]	***[-low]***	
		[coronal]	
	[-labial]	[-labial]	
	[tense]	[tense]	2

Note. The conjugate features are bolded and in italics.

(table continues)

Diphthong	Contrast		Level of featural
	1st element	2nd element	complexity
ɐi	ɐ	i	
	[-high]	***[+high]***	
	[+low]	***[-low]***	
		[coronal]	
	[-labial]	[-labial]	
	[lax]	***[tense]***	3
ɔi	ɔ	i	
	[-high]	***[+high]***	
	[-low]	[-low]	
	[dorsal]	***[coronal]***	
	[+labial]	***[-labial]***	
	[tense]	[tense]	3
au	a	u	
	[-high]	***[+high]***	
	[+low]	***[-low]***	
		[dorsal]	
	[-labial]	***[+labial]***	
	[tense]	[tense]	3

Note. The conjugate features are bolded and in italics

(table continues)

Diphthong	Contrast: 1st element	Contrast: 2nd element	Level of featural complexity
ɐu	ɐ	u	
	[-high]	***[+high]***	
	[+low]	***[-low]***	
		[dorsal]	
	[-labial]	***[+labial]***	
	[lax]	***[tense]***	4

Note. The conjugate features are bolded in italics.

Appendix B

Table B1

Individuals' Accuracy of Vowel Realization (15-18 months)

Subject No.	a	ɛ	ɐ	i	œ	y	ɔ	u
11	100% (2/2)	100% (5/5)	50% (2/4)	86% (6/7)	--	--	100% (11/11)	--
12	100% (14/14)	100% (2/2)	--	1/1	--	100% (2/2)	100% (4/4)	--
13	100% (4/4)	100% (5/5)	1/1	100% (4/4)	--	100% (2/2)	1/1	--
14	100% (7/7)	75% (3/4)	67% (2/3)	50% (3/6)	--	33% (2/6)	95% (18/19)	--
15	100% (3/3)	56% (5/9)	--	79% (5/7)	--	100% (9/9)	0% (0/4)	--
16	100% (4/4)	--	--	--	--	--	--	--
17	--	96% (47/49)	--	--	--	--	--	--
18	1/1	--	--	--	--	100% (6/6)	100% (2/2)	--
19	--	--	--	33% (1/3)	1/1	--	100% (8/8)	--
20	100% (2/2)	86% (6/7)	--	100% (2/2)	--	0/1	--	--

(table continues)

	a	ɛ	ɐ	i	œ	y	ɔ	u
Maximum	100%	100%	67%	100%	--	100%	100%	--
Minimum	100%	56%	50%	33%	--	33%	0%	--
Mean accuracy (%)	70%	61%	12%	45%	--	43%	50%	--
No. of subject with ≥75% accuracy	7	6	1	4	--	4	5	--

Table B2

Individuals' Accuracy of Vowel Realization (20-23 months)

Subject No.	a	ε	ɐ	i	œ	y	ɔ	u
21	100%	100%	--	92%	100%	67%	100%	67%
	(48/48)	(6/6)		(11/12)	(4/4)	(4/6)	(3/3)	(4/6)
22	1/1	--	--	50%	--	0%	85%	--
				(2/4)		(0/2)	(11/13)	
23	100%	100%	0%	100%	0%	--	--	83%
	(14/14)	(8/8)	(0/6)	(30/30)	(0/2)			(5/6)
24	100%	100%	100%	0/1	--	--	86%	--
	(10/10)	(3/3)	(2/2)				(6/7)	
25	100%	100%	100%	100%	0%	27%	100%	100%
	(11/11)	(3/3)	(8/8)	(7/7)	(0/2)	(3/11)	(6/6)	(7/7)
26	100%	100%	90%	95%	1/1	91%	96%	67%
	(13/13)	(11/11)	(9/10)	(21/22)		(10/11)	(22/23)	(6/9)
27	--	--	1/1	--	--	--	100%	--
							(2/2)	
28	100%	88%	1/1	93%	50%	89%	80%	1/1
	(16/16)	(14/16)		(14/15)	(1/2)	(8/9)	(4/5)	
29	69%	1/1	90%	95%	100%	0%	100%	57%
	(11/16)		(9/10)	(52/55)	(2/2)	(0/2)	(21/21)	(4/7)
30	100%	100%	100%	100%	100%	100%	86%	100%
	(26/26)	(20/20)	(5/5)	(29/29)	(4/4)	(14/14)	(30/35)	(4/4)

(table continues)

	a	ɛ	ɐ	i	œ	y	ɔ	u
Maximum	100%	100%	100%	100%	100%	100%	100%	100%
Minimum	69%	88%	0%	50%	0%	0%	80%	57%
Mean accuracy (%)	77%	69%	48%	73%	35%	37%	83%	47%
No. of subject with ≥ 75% accuracy	7	7	5	7	3	3	9	3

Table B3

Individuals' Accuracy of Vowel Realization (24-27 months)

Subject No.	a	ɛ	ɐ	i	œ	y	ɔ	u
31	100%	100%	88%	97%	67%	0%	83%	100%
	(11/11)	(3/3)	(7/8)	(32/33)	(4/6)	(0/2)	(20/28)	(5/5)
32	80%	100%	100%	100%	100%	100%	98%	100%
	(12/15)	(5/5)	(4/4)	(52/52)	(4/4)	(2/2)	(51/52)	(2/2)
33	71%	100%	100%	98%	75%	94%	95%	86%
	(5/7)	(11/11)	(18/18)	(40/41)	(6/8)	(16/17)	(35/37)	(6/7)
34	94%	100%	96%	100%	100%	--	83%	1/1
	(15/16)	(20/20)	(26/27)	(5/5)	(2/2)		(10/12)	
35	88%	88%	83%	96%	75%	80%	94%	86%
	(21/24)	(14/16)	(15/18)	(22/23)	(9/12)	(8/10)	(15/16)	(6/7)
36	87%	100%	100%	92%	50%	89%	100%	56%
	(20/23)	(13/13)	(20/20)	(24/26)	(1/2)	(8/9)	(5/5)	(5/9)
37	92%	100%	50%	67%	33%	50%	100%	50%
	(11/12)	(10/10)	(4/8)	(10/15)	(2/6)	(6/12)	(9/9)	(4/8)
38	100%	90%	89%	91%	100%	93%	88%	93%
	(31/31)	(26/29)	(8/9)	(21/23)	(15/15)	(14/15)	(23/26)	(13/14)
39	100%	100%	100%	100%	67%	1/1	100%	38%
	(39/39)	(13/13)	(6/6)	(44/44)	(2/3)		(25/25)	(3/8)
40	100%	100%	67%	64%	--	78%	92%	--
	(4/4)	(14/14)	(2/3)	(14/22)		(7/9)	(12/13)	

(table continues)

	a	ɛ	ɐ	i	œ	y	ɔ	u
Maximum	100%	100%	100%	100%	100%	100%	100%	100%
Minimum	71%	88%	50%	64%	33%	0%	83%	38%
Mean accuracy (%)	91%	98%	87%	91%	67%	58%	93%	61%
No. of subject with ≥ 75% accuracy	9	10	8	8	5	6	10	5

Appendix C

Table C1

Phonemic Realization of Single Vowels

Target vowel	Children's realization									
	i	ɛ	y	a	ə	ɐ	œ	ɔ	u	others
i		***60.0%***	22.8%	2.9%	8.6%					5.7%
y	***72.7%***	3.0%			6.0%		15.3%			3.0%
u	8.3%			8.3%				***79.2%***		4.2%
ɛ	11.1%			22.2%	***44.4%***					22.2%
ɔ	10.0%			***45.0%***					15.0%	25.0%
œ	5.6%	11.1%		***33.3%***		27.8%		16.7%		5.6%
ɐ	21.1%	10.5%		***52.6%***	10.5%			9.1%		5.3%
a						***88.2%***		5.9%		5.9%

Note. Others included the errors of deletion or diphthonization. The prominent error patterns are bolded and in italics

Appendix D

Table D1

Individuals' Accuracy of Diphthong Realization (15-18 months)

Subject No.	ei	ou	œy	iu	ui	ai	ɐi	ɔi	au	ɐu
11	89%	100%	--	67%	1/1	--	100%	1/1	--	1/1
	(8/9)	(6/6)		(2/3)			(2/2)			
12	1/1	1/1	--	1/1	--	--	--	--	--	--
13	100%	--	--	--	--	--	25%	--	--	--
	(2/2)						(1/4)			
14	33%	100%	50%	--	--	1/1	--	--	--	--
	(2/6)	(3/3)	(1/2)							
15	--	--	1/1	0%	0%	--	12.5%	--	8%	--
				(0/2)	(0/4)		(1/8)		(1/13)	
16	0/1	--	--	0%	--	--	--	--	10%	--
				(0/2)					(3/29)	
17	--	--	--	--	--	--	--	--	--	--
18	--	--	--	0%	--	--	--	--	--	--
				(0/2)						
19	100%	--	--	--	--	1/1	0/1	--	--	--
	(3/3)									
20	--	0%	0%	--	--	--	--	--	--	--
		(0/2)	(0/2)							

(table continues)

	ei	ou	œy	iu	ui	ai	ɐi	ɔi	au	ɐu
Maximum	100%	100%	50%	67%	--	--	100%	--	10%	--
Minimum	33%	0%	0%	0%	0%	--	12.5%	--	8%	--
Mean accuracy (%)	32%	20%	5%	6.7%	--	--	13.8%	--	1.8%	--
No. of subject with ≥75% accuracy	3	3	0	0	--	0	1	--	0	--

Table D2

Individuals' Accuracy of Diphthong Realization (20-23 months)

Subject No	ei	ou	œy	iu	ui	ai	ɐi	ɔi	au	ɐu
21	25%	50%	100%	67%	100%	--	1/1	0%	54%	100%
	(2/8)	(6/12)	(3/3)	(2/3)	(4/4)			(0/6)	(7/13)	(3/3)
22	--	50%	--	--	--	67%	--	--	--	--
		(1/2)				(2/3)				
23	--	100%	--	67%	--	--	--	--	100%	--
		(6/6)		(2/3)					(2/2)	
24	0%	0%	1/1	--	--	0/1	--	--	--	--
	(0/6)	(0/2)								
25	100%	95%	33%	100%	--	1/1	86%	1/1	100%	100%
	(2/2)	(20/21)	(1/3)	(4/4)			(30/35)		(4/4)	(10/10)
26	100%	100%	1/1	75%	100%	0/1	56%	100%	0%	78%
	(12/12)	(6/6)		(3/4)	(5/5)		(9/16)	(9/9)	(0/4)	(7/9)
27	--	--	--	--	--	--	--	--	--	--
28	100%	80%	--	--	0%	--	67%	--	--	0%
	(7/7)	(16/20)			(0/2)		(4/6)			(0/2)
29	100%	91%	100%	1/1	1/1	100%	78%	1/1	100%	100%
	(8/8)	(20/22)	(2/2)			(2/2)	(29/37)		(6/6)	(3/3)
30	100%	100%	0/1	87%	--	--	70%	1/1	--	100%
	(7/7)	(21/21)		(13/15)			(7/10)			(3/3)

(table continues)

	ei	ou	œy	iu	ui	ai	ɐi	ɔi	au	ɐu
Maximum	100%	100%	100%	100%	100%	100%	86%	100%	100%	100%
Minimum	0%	0%	33%	67%	0%	67%	56%	0%	0%	0%
Mean accuracy (%)	53%	67%	23%	40%	20%	17%	36%	10%	35%	48%
No. of subject with ≥ 75% accuracy	5	6	1	3	2	1	2	1	3	4

Table D3

Individuals' Accuracy of Diphthong Realization (24-27 months)

Subject No.	ei	ou	œy	iu	ui	ai	ɐi	ɔi	au	ɐu
31	100% (17/17)	100% (14/14)	1/1	--	--	100% (2/2)	83% (5/6)	100% (3/3)	--	1/1
32	0/1	94% (15/16)	67% (2/3)	--	--	1/1	100% (6/6)	--	1/1	100% (17/17)
33	90% (9/10)	95% (21/22)	100% (4/4)	100% (13/13)	--	50% (1/2)	100% (14/14)	100% (2/2)	40% (2/5)	100% (18/18)
34	100% (2/2)	61% (11/18)	--	14% (1/7)	--	0% (0/2)	67% (2/3)	--	100% (2/2)	100% (3/3)
35	100% (15/15)	72% (20/24)	0/1	78% (7/9)	100% (2/2)	--	93% (13/14)	1/1	67% (2/3)	78% (7/9)
36	100% (6/6)	74% (14/19)	0/1	100% (2/2)	--	50% (1/2)	67% (2/3)	60% (3/5)	67% (2/3)	100% (3/3)
37	50% (1/2)	86% (12/14)	--	70% (7/10)	--	29% (2/7)	29% (2/7)	0/1	75% (3/4)	79% (11/14)
38	100% (7/7)	100% (11/11)	1/1	100% (2/2)	--	67% (2/3)	75% (9/12)	100% (5/5)	50% (1/2)	75% (3/4)
39	100% (5/5)	91% (31/34)	100% (8/8)	--	--	100% (5/5)	91% (42/46)	50% (2/4)	1/1	100% (6/6)
40	1/1	83% (10/12)	--	100% (2/2)	--	100% (2/2)	88% (15/17)	100% (2/2)	100% (4/4)	1/1

(table continue

	ei	ou	œy	iu	ui	ai	ɐi	ɔi	ɐu	ɐu
Maximum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Minimum	50%	61%	67%	14%	--	0%	29%	50%	40%	75%
Mean accuracy (%)	74%	86%	27%	56%	10%	50%	79%	51%	50%	73%
No. of subject with ≥ 75% accuracy	7	7	2	5	1	3	7	4	3	7

Target diphthong	Children's realization																
	i	ɛ	œ	ɔ	a	ɐ	y	u	ə	ei	ou	ɐu	au	ɐi	ai	ɛu	others
ei	28.6%	***42.9%***			23.8%							4.7%					
œy			***44.4%***		11.1%	11.1%				33.3%							
ou	4.7%			***39.5%***	4.7%			11.6%	2.3%	7.0%		14.0%	11.6%	2.3%			2.3%
iu	***45.6%***	22.7%					4.5%						4.5%			22.7%	
ui	33.3%	***67.7%****															
ai		7.1%			***78.6%***			7.1%						7.1%			
ɐi	11.5%	17.3%		3.8%	7.7%				3.8%	***46.2%***					9.6%		
au					***74.5%***							3.9%			21.6%		
ɔi				***36.4%***	36.4%*										27.2%		
ɐu					***50.0%***						40.0%		10.0%				

Note. Others included all deletions. The prominent error patterns are bolded and in italics. The prominent error pattern shown in one subject is marked with an asterisk.