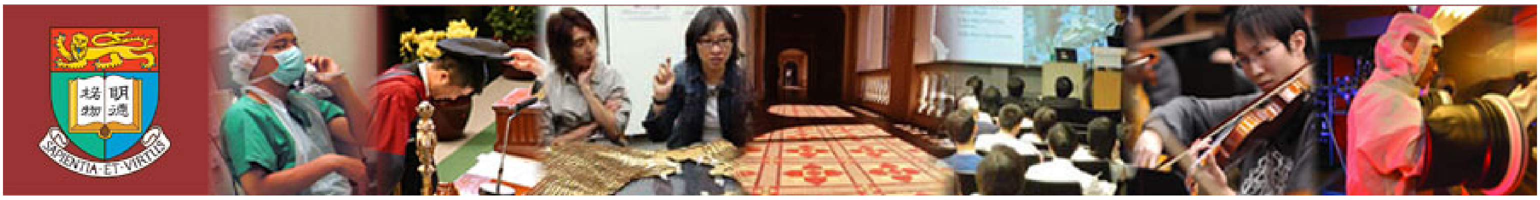

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NOTE

Cantonese consonantal development: towards a nonlinear account*

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ABSTRACT

Descriptions of the development of prosodic and segmental tiers of children's phonological systems have been derived from investigations of the development of English. This paper provides a preliminary description of phonological tier development in Cantonese-speaking children. Eight children, (two each at 1;7, 2;6, 3;5, and 4;2 years) named 95 pictures. The data were analysed for word, syllable, onset-rime, skeletal, and segmental tiers. The results suggested a developmental order in the acquisition of hierarchical features. Decreasing order of accuracy of the tiers was word = syllable > onset-rime = skeletal > segmental. A model of feature geometry was adopted to describe the acquisition of features. An interesting finding is the way the laryngeal feature (aspiration) was combined with place contrasts one at a time rather than all at once.

INTRODUCTION

Two major approaches have been applied to developmental phonology: linear and nonlinear. Linear phonology analyses speech in terms of individual distinctive segments (i.e. phonemes), and assumes that the segments occur one-by-one serially in a linear manner, whereas nonlinear phonology assumes that features can extend over more than one segment. The linear approach has been applied to Cantonese developmental phonology in descriptions of

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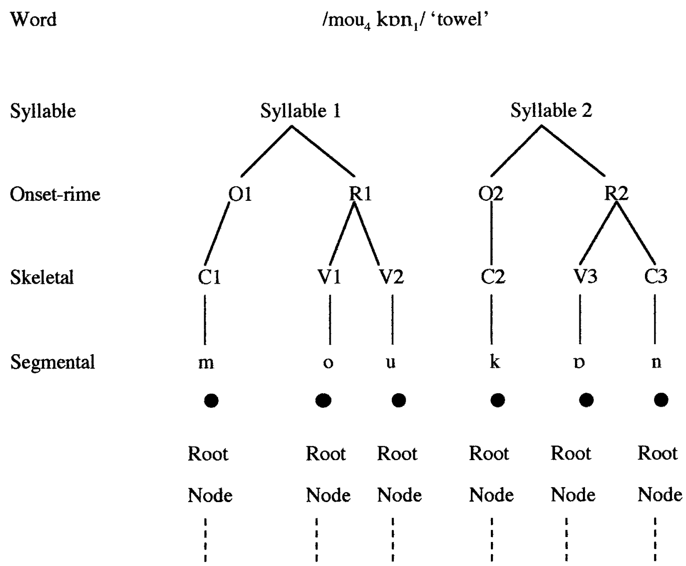

Fig. 1. Prosodic and segmental tiers for Cantonese.

the chronological sequence of acquisition of phonemes (e.g. So & Dodd, 1995), and the description of error productions of phonemes in terms of phonological processes by relating children's realizations to their target (adult) realization (e.g. So & Dodd, 1995). However, it has been claimed that the unit of phonological representation is not only the segment. Evidence from English suggests that phonological acquisition in the early stages is word-based (Macken, 1993) or syllable-based (Stoel-Gammon & Dunn, 1985.). Phonemes and features become the basic units at a later stage of development. The fact that the acquisition of phonemes is dependent on their word position (Stoel-Gammon & Dunn, 1985) or features (Dinnsen, Chin, Elbert & Powell, 1990) provides support for this claim.

Therefore in this paper we apply a non-linear phonological framework to the analysis of data from Cantonese-speaking children, as an initial test of the validity of this representational system on a language whose development has not yet been described from a nonlinear perspective.

Cantonese in a nonlinear framework

Cantonese is a Chinese dialect spoken by some 40 million speakers worldwide (Bauer & Benedict, 1997). Here we briefly describe four aspects of Cantonese within a nonlinear framework. Briefly, nonlinear phonology assumes that there are hierarchically organized levels of phonological representation (tiers) (Bernhardt & Stoel-Gammon, 1994): the prosodic tier and the segmental (or melodic) tier. The structure and composition of tiers is controversial (Goldsmith, 1995) and as the scope of this investigation is limited to a discussion of syllable shape, onset-rime, the skeletal tier, and the features of consonants we do not address stress, tones or vowels in this investigation. Thus for our purposes, the prosodic tier contains the word, syllable, onset-rime, and skeletal tiers (Fee, 1995; McCarthy & Prince, 1999; Selkirk, 1999).

The Cantonese system differs from English on four major dimensions: phonotactic structure, tone, number of contrastive consonants, and aspiration. The phonotactic structure is relatively simple. The most complex syllable structure is CVC or CVV. All roots are monosyllabic. Figure 1 provides a representation of the Cantonese disyllabic word /mou$_4$kɒn$_1$/ (towel).

Each syllable is composed of an onset and a rime. The onset is a prevocalic consonant or a vowel (e.g. /sy$_6$/ *-leaf*, /ap$_3$/ *-duck*). The rime may be one of two types: a nucleus only (consisting of a long vowel or a consonant), or a vocalic nucleus plus coda (e.g. /mau$_5$/, /min$_2$/). Codas can be vowels (/u/, /i/ or /y/), nasal consonants (/m/, /n/, /ŋ/), or unreleased plosives (/p̚/, /t̚/, /k̚/). The skeletal tier provides time slots (x-slots) for segments. Table 1 shows the consonant segments that occur at initial (19 segments) and final

TABLE 1. *Cantonese consonants*

	Labial	Alveolar	Palatal	Velar	Glottal
Syllable initial					
Nasal	m	n		ŋ	
Plosive	p p^h	t t^h		k k^h k^w k^{wh}	
Affricate		ts ts^h			
Fricative	f	s			h
Approximant	w	l	j		
Syllable final	m p̚	n t̚		k̚ ŋ	

positions (six segments) in the phonotactic structure. There are no clusters in Cantonese – /k^w/ and /k^{wh}/ are analysed as labialised velars as they are coarticulated and are thus single segments, not clusters (Bauer & Benedict, 1997). Therefore /k^w/ and /k^{wh}/ occupy only a single x-slot (C) in the skeletal tier (Sagey, 1990).

In Cantonese the first slot will always associate with the first root consonant, the second slot with the vowel and the final slot with a coda consonant, coda vowel, or the second mora of a long vowel (Yip, 1997). There are eleven vowels (i, y, ɛ, ɔ, œ, ɒ, u, ʊ, e, ɑ, ɪ) and ten diphthongs (ɒi, ɑi, ɒu, ɑu, ei, ey, ɔi, ui, iu, ou). Children developing normally acquire vowels before the age of two (Tse, 1991). Vowels are not considered further in this discussion.

The predominant (root) structure is CVC, with CVV and CV occurring frequently. The existence of a phonotactic structure of /V/ only, or /VC/ is contentious, as Yip (1997) claims that these syllables actually carry an initial velar nasal /ŋ/ which is optionally deleted. Here we accept the legitimacy of both /V/ and /VC/ as phonotactic structures. The nature of the coda is also contentious, as some authors describe the second component of the diphthong as a semivowel (for example, Bauer & Benedict, 1997; Yip, 1997).

There is a merger of [n-] with [l-] in Cantonese where in most cases [l-] is produced in favor of [n] (Cheung, 1986). This has implications for the profiling of Cantonese phonological development, as an absence of /n/ is not considered abnormal. Briefly, the range of manners of production is almost the same as English (nasal, plosive, affricate, fricative, approximant), except that there is no rhotic in Cantonese. The distribution of manner of production across place of articulation and laryngeal involvement is however quite different. For example, fricatives occur at labial (/f/), alveolar (/s/) and glottal (/h/) positions only. Affricates occur at alveolar position only. For a review of the place of articulation of Cantonese lingual consonants, see Kwok & Stokes (1997). With regard to laryngeal features, all Cantonese stops, fricatives and affricates are unvoiced. The stops and affricates have aspirated and unaspirated pairs. As with the unvoiced/voiced contrast in English, the aspirated/unaspirated contrast in Cantonese is phonemic. For a description of the development of Cantonese aspiration see Stokes & Ciocca (1999).

Unlike English, Cantonese has tone as a contrastive feature. There are six lexical tones in Cantonese, high-level (subscript 1 for example /hœŋ_1 tsiu_1/ = *banana*), high-rising (subscript 2), mid-level (subscript 3), low-level (subscript 4), low-rising (subscript 5), and low-falling (subscript 6) (Cheung, 1986). We assume that tone is part of the prosodic tier (Odden, 1995; 1999). Tonal contrasts are reported to develop early in Cantonese children's speech (So & Dodd, 1995), but we do not pursue issues relating to tone in this report. In summary, the simplest Cantonese phonotactic structure is $C_{sonorant}$ + tone or V + tone, and the most complex is CVC + tone or CVV + tone.

In describing the prosodic features of Cantonese, a further complication arises. There are several essentially morphological or sociolinguistic devices common in Cantonese, which are as yet unexplored and which, if not considered cautiously, may lead to an overestimation or underestimation of a child's phonological system. Certain words in Cantonese allow more than one possible number of syllables. For example, the word *leaf* may be realised as mono- or di- syllabic – [jip_6] = *leaf*, or [sy_6 jip_6] where the structure is a NN = *tree leaf*. Also, full reduplication is an input device used by parents and adopted by children with the resulting production being variably mono- or di- syllabic, for example *shoe* may be [hai_4] or [hai_4hai_4] and likewise, in child-directed speech adults produce disyllabic words as a reduplication of one syllable, for example /hœŋ$_1$ tsiu$_1$/ (*banana*) becomes [tsiu$_1$ tsiu$_1$] both in adult input and in the lexicons of young children. These morphological and sociolinguistic devices have an impact on the coding system used in the phonological analysis outlined below in the methodology section. One further aspect of Cantonese phonotactics which deserves mention is that some adult words have the shape $C_1V_1C_1V_1$ such as *sister* – /tse$_4$ tse$_2$/ and *grandmother* – /p^{h}ɔ$_4$ p^{h}ɔ$_1$/.

At the segmental level, according to models of feature geometry (Sagey, 1990), each segment is composed of hierarchically organized features, such that if a rule spreads or delinks a node, all of the subordinate structures will also be affected (Dinnsen, 1997). Figure 2 shows the feature geometry for

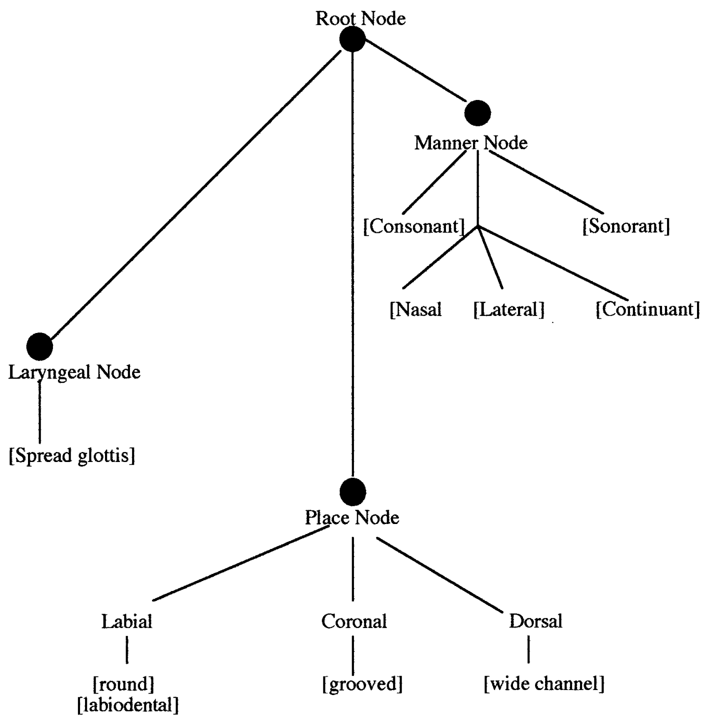

Fig. 2. Feature geometry for Cantonese.

Cantonese, which is modified based on McCarthy (1988), and Bernhardt & Stemberger (1998).

The manner node contains the major class features of [sonorant] and [consonantal], and the secondary manner features of [continuant], [nasal], and [lateral]. The laryngeal node feature, [spread glottis] denotes fricatives and aspirated phonemes. The place node has high-level place features –

[Labial], [Coronal], and [Dorsal], and their corresponding low-level place features – [round], [labiodental], [grooved], [wide channel].

METHOD

Subjects

The subjects were eight Cantonese-speaking children, two each (one male and one female) at 1;7, 2;6, 3;5 and 4;2 years. Based on previous literature, we expected these subjects to demonstrate a steady increase in phonological competence at these four age points (So & Dodd, 1995). All subjects met the following four selection criteria. They had (a) no reported organic, gross neurological, visual, emotional, nor inherited disorders, (b) age-appropriate language skills as assessed by the Reynell Developmental Language Scale (Reynell, 1987, Revised Cantonese version), (c) normal hearing; the hearing status of the youngest group of subjects was screened by using visual reinforcement audiometry and that of the other subjects was screened at octave frequencies across 500–4000 Hz at 20 dBHL (American National Standards Institute, 1970), and (d) normal oral-motor functioning as determined by an oral-motor examination.

Data collection

The subjects named 95 pictures that were selected to ensure elicitation of five productions of each initial Cantonese phoneme. The target words were either monosyllabic or disyllabic. Since this study aims at the exploration of development of INITIAL CONSONANTS, the syllable structures were CV, CVC, and CVV. The assessment was completed within 1.5 hours. The data were recorded on a Sony Minidisc and transcribed phonetically by the first author. Point-to-point intra-rater and inter-rater reliability (by a person trained in phonetics) checks on initial consonants were conducted on 10% of the data. Intra-rater reliability was 96.5% and inter-rater reliability was 93.8%.

Data analysis

The data were analysed for two main aspects. First, on the word, syllable, onset-rime, skeletal, and segmental tiers, matches between the child's attempts and the target phonemes were calculated. Second, the acquisition of features was analysed according to the model of feature geometry proposed for Cantonese. A developmental sequence of the hierarchical structures was constructed, with a focus on the consonants. The following section explains the criteria for calculating the percentage match for each tier.

Criteria for calculating the percentage match at the prosodic (word, syllable, onset-rime and skeletal tiers) and segmental tiers

Word tier. Productions that resulted from the application of certain templates (C-V patterns) were treated as mismatches on the word tier. If a word shape arises that fits into a pattern adopted by a given child (for example, a restricted C-V pattern), then that word shape (prosodic word) is said to be the result of the application of a particular template (or pattern) (McCarthy & Prince, 1999; Prince, 1999). For example, harmony templates involve the presence of consonant or vowel assimilation. They can be consonant harmony templates, C_1V C_1V (e.g. /doli/ → [dodi]) or vowel assimilations (e.g. CV_1 CV_1 /fɛɹi/ → [fiwi]). In melody templates segmental features co-occur in specific phonotactic positions and in a particular order (Macken, 1995). For example, Vihman (1996) outlines Macken's (1979) description of one child's co-occurrence restrictions, which allowed only certain types of across-syllable combinations. When the child's consonantal system consisted of only [p, t, m, n, w, j] her co-occurrence restriction stated that if C_1 was a labial then C_2 had to be coronal ([t]). At the same time, a glide in C_1 could co-occur with either stops or nasals in C_2 (for example [wVtV], [wVnV]). These word templates do not reflect difficulties on the segment tier, but rather on the prosodic tier. Therefore, word productions that could be attributed to a word-template were excluded from the analyses on the onset-rime, skeletal and segmental tiers, for example aeroplane /fei_1 kei_1/ realised as [fi_1 ki_1] or *fish* /jy_2/ realised as [a_6 jy_2]. That is, if productions that arise from the use of word templates were included in the analysis, the result would be a miscount of matches for onset-rime, skeletal and segmental tiers. Take the above example of aeroplane /fei_1 kei_1/ realised as [fi_1 ki_1]. The target word has a syllable shape of $C_1V_1V_2$ $C_2V_1V_2$. The child's production is C_1V_1 C_2V_1. We cannot determine whether the omission of part of the rime can be attributed to syllable 1 or syllable 2, and this lack of clarity is compounded if the child accurately produced the full rime in another word (e.g. you /lei_5/). Likewise, it would be erroneous to count an error of the vowel /e/ at the segmental level (if the vowels were included in the analysis, which they are not in this investigation). Therefore, where errors cannot be clearly categorized, as happens when a child uses a word template, these errors were excluded from subsequent analysis.

Syllable tier. Syllable deletions or additions were treated as mismatches on the syllable tier. Due to the current lack of knowledge about the relationship between adult and child productions, our coding system for Cantonese differs from that used for English. That is, if a child realized the monosyllabic target word for the elicitation picture as full reduplication (e.g. /hai_4/ – *shoe* ([hai_4 hai_4]), this was counted as a correct realization of the monosyllabic target. As mentioned previously, certain words allow more than one possible number of syllables. Therefore, if a monosyllabic target word for an elicitation picture was realized as more than one syllable (e.g. /jip_6/ – *leaf* ([sy_6 jip_6]) this was also counted as a correct realization of the monosyllabic target. If a disyllabic target word was realized as more than two syllables (e.g.

/jɑu$_4$ ts^{h}ai$_1$/ – *postman* ([jɑu$_4$ ts^{h}ai$_1$ sʊk$_1$ sʊk$_1$] – *uncle postman*), this was counted as a correct realization of the disyllable target. Target words which are normally reduplicated, except for tone (e.g. /p^{h}ɔ$_4$ p^{h}ɔ$_2$/ = *grandmother*, /tsɛ$_4$ tsɛ$_1$/ = *sister*) were treated as disyllabic words, not as full reduplications. For reduplicated target words and full reduplications, only one of the syllables was included in the onset-rime, skeletal, and segmental tier analyses. All partial reduplications (e.g. /hai$_4$ hai$_4$/ – *shoe* ([ha$_4$ hai$_4$]) were excluded from the onset-rime, skeletal and segmental tier analyses, as there are no obvious criteria as to which one of the syllables should be selected for analysis. Therefore, only clear violations of the target syllable structure were coded as mismatches, for example one child's omission of the first syllable from a disyllabic target or addition of the syllable /a/ to monosyllabic targets. Where the child produced only one syllable of a two syllable word (for example /kei$_1$/ for [fei$_1$ kei$_1$]), an error was counted at the syllabic level, since it is assumed that the child has retrieved the correct label for the picture, but not encoded both syllables.

Onset-rime tier. Since /ŋ -/ is becoming optional in Cantonese, deletion of [ŋ -] was not counted as a mismatch in the onsets. Instead, the target occurrences were EXCLUDED FROM THE ANALYSES in the onset-rime, skeletal and segmental tiers. (For example, /ŋɔ$_5$/ (*I*) is commonly produced as [ɔ$_5$] by the younger generation in Hong Kong.) Deletions of onset or rime were counted as mismatches, (for example /ap$_3$/ → [a$_3$] (*duck*) is a deletion of rime.)

Skeletal tier. Deletions or additions in x-slots were counted as mismatches. (For example /hai$_4$/ (*shoe*) → [ha$_4$] is a deletion of V_2 in the skeletal frame of CVV, and /fa$_{55}$/ (*flower*) → [faʔ$_{55}$] is an addition of a C to the skeletal frame of CV.)

Segmental tier. Any consonant attempted by the subject less than twice was treated as missing data. Lateralized /s/ was treated as a mismatch because the feature criteria for /s/ include [+grooved]. The possibility that mismatches could have been caused by a consonant harmony effect (e.g. /sɪk$_1$/ ([kɪk$_1$]) was not taken into account since there are no criteria as to whether the mismatches were purely caused by harmony.

RESULTS AND DISCUSSION

Developmental pattern

To look for a developmental pattern across the tiers, the percentage accuracy of production on the word, syllable, onset-rime, skeletal, and segmental tiers of each subject was examined. As the systems of the older children were well established, here we focus on the two younger children (summarized in Table 2).

TABLE 2. *Percentage of accuracy of productions at the word, syllable, onset-rime, skeletal, and segmental tiers for 1;7M and 1;8F.*

		Syllable		Onset-rime				Skeletal						
	Word	1 syll	2 syll	O1	R1	O2	R2	C1	V1	C2	C3	V2	C4	Segment
1;7/M	88	100	100	95	81	100	100	95	100	68	100	100	–	83
1;8/F	91	100	38	93	82	98	96	93	99	75	98	100	94	48

–, no data; M, Male; F, Female; syll, Syllable; O1, Onset of first syllable; R1, Rime of first syllable; C1, Consonant of first syllable; V1, Vowel of first syllable.

The accuracy for the prosodic tiers (i.e. the word, syllable, onset-rime, and skeletal tiers) was higher than for the segmental tier in all subjects. Thus the descending order of accuracy from the within-subject comparison was prosodic tiers > melodic tier. Of the six older children, three produced mismatches on the skeletal tier, but accuracy was over 95%; on the segmental tier, all six of the older children produced errors (accuracy varied from 55–96%). Therefore the decreasing order of accuracy was word = syllable > onset-rime = skeletal > segmental tier.

Productions on each tier

This section describes the specific patterns of productions on each tier (refer also to Table 2). Word, syllable, onset-rime and skeletal tiers were remarkably accurate, with errors limited almost exclusively to the very youngest subjects. On the word tier, productions of prosodic words which revealed a word-template were treated as mismatches with the target words. Only subjects 1;7M and 1;8F produced prosodic words that could be attributed to a prosodic template, and these were only of the following types. Subject 1;7M produced words with (a) a harmony template of [Ci Ci] e.g. aeroplane /fei_1 kei_1/: [fi_1 ki_1]; cup /pui_1 pui_1/: [wi_1 wi_3]; or (b) a melody template of [CV Ci] e.g. cup /pui_1 pui_1/: [pu_1 pi_1]; bowl /wun_2 wun_2/: [wu_2 wi_2]; biscuit /$pɛŋ_2$ $pɛŋ_2$ /: [$pɛ_2$ pi_2]. That is 1;7M's co-occurrence constraint was [CV Ci] .

Subject 1;8F produced words with the specific pattern of [a]+syllable. For example, she imitated *fish* /jy_2/ as [a_6 jy_2]; spontaneously produced *water* /$sœi_2$/as [a_3 $tœi_2$]; imitated *mouse* /lou_5 sy_2/ as [a_5 ty_2]. This pattern was categorized as a TEMPLATE PRODUCTION. These types of productions were excluded from the analysis of onset-rime, skeletal and segmental tiers.

On the syllable tier while all other subjects had 100% accuracy, subject 1;8F had an accuracy of 38% for disyllabic words. She deleted the FIRST syllable in twenty-six of the disyllabic target words, e.g. *bee* /$mɒt_6fʊŋ_1$/: [$fʊŋ_1$]. Syllable additions occurred only in the [a]+syllable template productions. Both syllable deletions and additions were counted as mismatches on the syllable tier.

There was high accuracy for the onset-rime and skeletal tiers at all ages except the youngest. Both 1;7M and 1;8F had reduced accuracy of onset and rime due to the omission of initial and coda consonants respectively.

Acquisition of features

For the segmental tier, the percentage match of each of the 19 initial consonants was calculated. Each subject's phonemic inventory was divided into three levels, based on the percentage match of each initial consonant:

Level I The 'acquired' level: equal to or greater than 75% match with the target.

TABLE 3. *Features in Levels I, II, and III of subject 1;8/F*

		Cumulative features		
	Phonemic inventory	Manner	Place	Laryngeal
Level I	m p t k h	Sonorant Consonantal Nasal	Labial Coronal Dorsal	Spread glottis (0)
Level II	p^h ts j ŋ	Continuant	Coronal: grooved Dorsal: wide channel	(1)
Level III	f, w, ts^h, s, t^h, l, k^h, k^w, k^{wh}	Lateral	Labial: round Labial: labiodental	(5)
Missing data	n			

Level II The 'developing' level: between 50% and 75% match with the target.

Level III The 'emerging' level: equal to or less than 50% match with the target.

Features that appear in the inventory for each level were then identified for each child (see Table 3 for an example). Acquisition was analysed in terms of feature values, rather than feature contrasts. [If the notion of feature contrasts is applied as in Rice & Avery (1995), the result will always be that high-level place features are acquired before low-level place features.]

First, the acquisition of features by subject 1;8F across levels I to III is presented to illustrate how the feature geometry model describes the developmental process in feature acquisition. Then the developmental sequence of features is proposed by a cross-subject comparison of level I (acquired) features and a within-subject comparison across acquisition of levels I, II, and III.

Feature acquisition in an example – Subject 1;8F (See Table 3 and Figure 3). In level I ($\geqslant 75\%$ match), the child had acquired the manner features [consonantal] (/p, t, k/), [sonorant] and [nasal] (/m/), as indicated by THE THIN LINES in Figure 3. All three high-level place features, [Labial], [Coronal], and [Dorsal] were also acquired which distinguish the segments /p/, /t/, and /k/ also indicated by THIN LINES in Figure 3.

The laryngeal feature [spread glottis] (/h/) was acquired but was restricted to the laryngeal node only, and had not combined with any of the place nodes, coded as [Spread] (o) in Figure 3. (Ladefoged & Maddieson (1996) argue that the shape of the vocal tract in the production of /h/ is often the same as that of the surrounding vowels, and hence that /h/ should be regarded as a segment having laryngeal specification only.)

At level II (50% match but $< 75\%$ match) indicated by the DASHED LINES in Figure 3, one more manner feature was developing, [continuant] (/ts/). Low-level place features [grooved] (/ts/) and [wide channel] (/j/) were also developing to this degree respectively. The dorsal nasal /ŋ/ was also developing. The laryngeal feature had started to combine with the [Labial] place node in /p^h/.

At level III ($\leqslant 50\%$ match), which is indicated by the THICK SOLID LINES in Figure 3, the manner feature [lateral] was emerging, which characterizes the segment /l/. The low-level place features [round] and [labiodental] under the [Labial] node were also emerging to distinguish the segments /w, k^w, k^{wh}/ and /f/ respectively. The laryngeal feature was spreading to the remaining place nodes to mark /t^h, k^h, ts^h, k^{wh}/ and the combination of [continuant] and [grooved] was beginning to emerge for /s/.

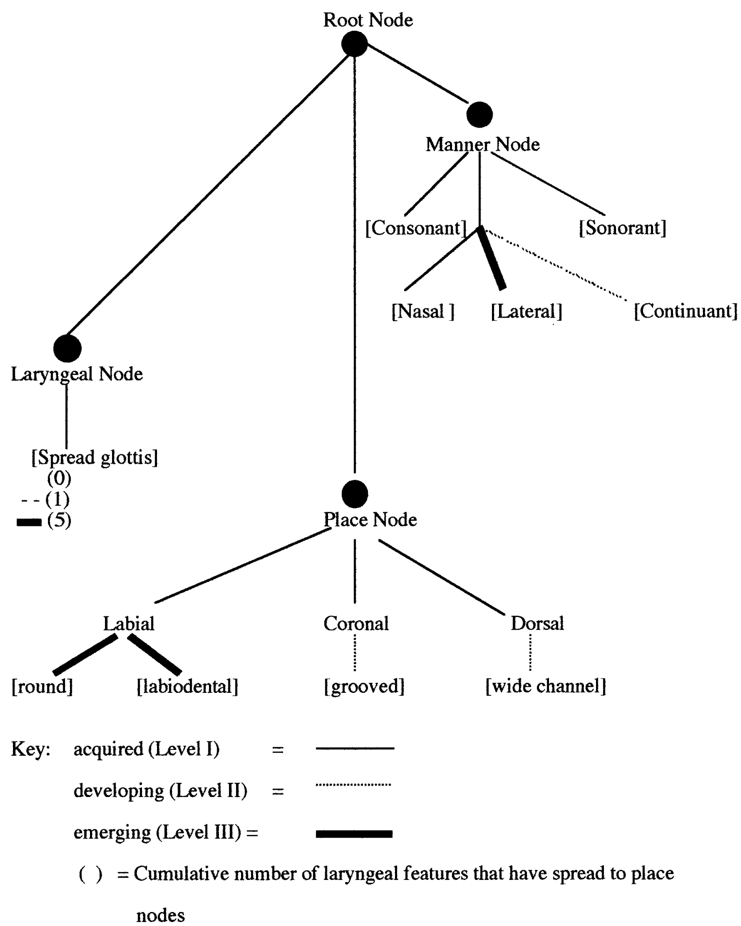

Fig. 3. Feature development in subject 1;8F.

Cross-subject comparison of level I (acquired) features. To look for a group pattern of the acquisition of features, the features acquired by each subject were compared across the age groups, from young to old (Table 4). Subject 1;7M was comparatively faster in acquisition than his counterpart and even had a more developed consonant system than a child one year older (2;7M). (He is considered further only in so far as his system reflects what seem to be common development trends, such as the spreading of the feature [spread glottis].)

Subjects 1;8F and 2;7M had acquired three manner features, while subject 2;6F and all other subjects beyond this age had acquired all the five manner features in Cantonese. Thus a developmental expansion in the

TABLE 4. *Acquired (level I) features in syllable-initial consonants across the age groups*

Child	Phonemic inventory	Acquired (Level I) features: Manner	Place			Laryngeal
1;7/M	m n p t k ts h w j	Sonorant Consonantal Continuant Nasal	Labial: round	Coronal: grooved	Dorsal: wide-channel	Spread glottis
1;8/F	m p t k h	Sonorant Consonantal Nasal	Labial	Coronal	Dorsal	Spread glottis
2;7/M	p/p^h t j	Sonorant Consonantal Continuant	Labial	Coronal	Dorsal: wide-channel	(1)
2;6/F	m n p^h t/t^h k/k^h k^w f ts h w l j	Sonorant Consonantal Continuant Nasal Lateral	Labial: round, labiodental	Coronal: grooved		(3)
3;6/M	m p/p^h t/t^h k/k^h f ts^h h w l j	All	All	All	All	(4)
3;/F	m p/p^h t/t^h k/k^h k^w/k^{wh} f ts/ts^h h w l j	All	All	All	All	(5)
4;4/m	m p/p^h t/t^h k/k^h k^w/k^{wh} f ts/ts^h h w l	All	All	All	No wide-channel	(5)
4;1/F	m p/p^h t/t^h k/k^h k^w/k^{wh} f ts/ts^h h w l j	All	All	All	All	(5)

Parentheses indicate the number of laryngeal features combined with place features, there is a maximum of 5 in Cantonese, including /p^h, t^h, k^h, ts^h, k^{wh}/. Blank cells contain features that are stated in the corresponding upper cell.

number of manner features was observed. Of all the manner features, [lateral] was the last one acquired.

The youngest subjects 1;7M and 1;8F had acquired the laryngeal feature (in [h]), but had not combined the feature with any of the place nodes. For subject 2;7M, the laryngeal feature was combined with one of the place features [Labial], while for subjects 2;6F and 3;6M, the laryngeal feature was combined with all three place features. For subjects 3;5F, 4;4M and 4;1F, the laryngeal feature was also combined with the coronal affricate. Thus there was a developmental progression in the combination of the laryngeal feature with place features.

The inventory of subject 1;8F included only the high-level place features. Subject 1;7M had 3 low level place features; [round], [grooved] and [wide channel]. Subject 2;7M had acquired the high-level place features plus only one low-level place feature ([wide channel]). Subjects 2;6F and all older subjects except 4;4M had acquired all the high-level and low-level place features.

Within-subject comparison across levels I, II, and III. The features acquired by subjects 1;8F and 2;7M across the three levels of acquisition are summarized in Tables 3 and 5. These two subjects showed a developmental expansion of

TABLE 5. *Features in levels I, II, and III of subject 2;7M*

		Cumulative features		
	Phonemic inventory	Manner	Place	Laryngeal
Level I	p/p^h t j	Sonorant Consonantal Continuant	Labial Coronal Dorsal: wide channel	Spread glottis (1)
Level II	m, w, f, t^h, l, k, k^h, h	Nasal Lateral	Labial: round labiodental	(3)
Level III	n, s, ts, ts^h, k^w, k^{wh}		Coronal: grooved	(5)
Outside his system	ŋ			

the number of manner features across levels I to III and I and II respectively. All other subjects (except 1;7M) had already developed the entire set of manner features in Cantonese at level I and are not described here. The mastery of all features by the child aged 3;5 deserves mention, as this is comparatively faster than English, probably reflecting the absence of a palatal fricative and consonant blends in Cantonese.

For subjects 1;8F and 2;7M there was a progressive acquisition of low-level place features across the three acquisition levels. The last 'emerging' low-level place features for subject 1;8F were under the [Labial] node, and that for subject 2;7M was under the [Coronal] node. There was no developmental priority of emergence of low-level place features amongst [Labial], [Coronal], or [Dorsal].

Summary of feature development

First, there was a developmental expansion in the repertoire of manner features. Second, the feature [lateral] emerged last among the manner features. Third, early inventories contained mainly high-level place features whereas later inventories also contained low-level place features. Fourth, there was a developmental progression in the addition of laryngeal features to the place nodes. Lastly, there was inter-subject variability in the rate of acquisition and in the acquisition order of low-level place features.

Psychological reality of the word tier representation

Subject 1;7M produced words that can be described as following a harmony template or a melodic template. Macken (1993) hypothesized that a child might formulate a word template, and generalize it to handle new words. This proposal seems to describe both the [CV Ci] template of this subject and the [a + syllable] template of subject 1;8F. Regarding the latter, in Cantonese, /a-/ is a prefix used with names and kinship terms (Matthews & Yip, 1994) for example, brother [a_3 $kɔ_1$], grandmother [a_3 $p^hɔ_4$], which were familiar names to this subject. Based on this evidence, we hypothesize that word information could be encoded as a whole word, rather than as segments. These findings provide support for the notion of a prosodic template in early phonological development.

Unique features of Cantonese

The high accuracy of the onset-rime and skeletal tiers may be characteristic of languages similar to Cantonese which have a simple syllable structure. Cantonese has a simple phonotactic structure ([C_{0-1}]-V-[V/C_{0-1}]) when compared with English ([C_{0-3}]-V-[C_{0-4}]). There are no clusters, and there are few final consonants in Cantonese. Also final consonant deletion has been shown to be rare after the age of two, according to the normative data in So & Dodd (1995). In contrast, the accuracy of the onset-rime and skeletal tiers in English should be lower than in Cantonese because in English, final consonant deletion persists in children up to 2;6–3;0 (Grunwell, 1982).

Developmental progression in feature co-occurrence

There was a developmental progression in the combination of laryngeal features with place of articulation. That is features are not learned ‘across the board’, as laryngeal features appear to be gradually combined with place of articulation, as proposed by Gierut's (1998) cyclicity theory. This developmental combination of features also implies that more specified segments are acquired later than less specified segments, that is segments that require a lesser degree of feature co-occurrence are acquired earlier than segments that require a higher degree of feature co-occurrence. For example, coarticulated phonemes /k^w, k^{wh}/ were acquired late, as reported by So & Dodd (1995) and Tse (1991). This can be explained by the issue of feature co-occurrence, in which segments /k^w, k^{wh}/ require co-occurrence of two place features [Labial: round] and [Dorsal]. Similarly, aspirated phonemes require an additional laryngeal feature as compared to their unaspirated counterparts. This might explain why aspirated phonemes were often acquired later than their unaspirated counterparts, as in the data of So & Dodd (1995).

The inventories of two of the younger subjects (1;8F and 2;7M) included [Dorsal] as well as [Labial] and [Coronal]. This finding may reflect the importance of phoneme frequency in a language (Stemberger & Stoel-Gammon 1991) since [Dorsal] occurs very frequently in Cantonese (Fok, 1979). This was not expected given our knowledge of English and the developmental Cantonese norms provided by So & Dodd (1995).

This study has provided preliminary data of the development of Cantonese from a nonlinear perspective. Given the small sample size, the findings require replication and validation, ideally via a longitudinal study. Nevertheless, the results do seem to indicate the feasibility of a nonlinear framework for capturing developmental progression in phonological development particularly providing valuable insights regarding word level representation.

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