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The acquisition of phonology by Cantonese-speaking children*

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ABSTRACT

Little is known about the acquisition of phonology by children learning Cantonese as their first language. This paper describes the phoneme repertoires and phonological error patterns used by 268 Cantonese-speaking children aged 2;0 to 6;0, as well as a longitudinal study of tone acquisition by four children aged 1;2 to 2;0. Children had mastered the contrastive use of tones and vowels by two years. While the order of acquisition of consonants was similar to that reported for English, the rate of acquisition was more rapid. The developmental error patterns used by more than 10% of children are also reported as common in other languages. However, specific rules associated with Cantonese phonology were also identified. Few phonological errors were made after age four. The results are consistent with the hypothesis that the ambient language influences the implementation of universal tendencies in phonological acquisition.

INTRODUCTION

The phonological development of children learning English as their first language has been well described (e.g. Smith, 1973; Ferguson & Farwell, 1975; Ingram, 1981). However, as Ingram (1989: 214) points out, 'Despite

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numerous studies on languages other than English we know relatively little about phonological development in other languages'. Nevertheless, the few crosslinguistic studies available have provided evidence bearing on some major theoretical issues in child phonology. Perhaps the most important question is how the phonological system being learned influences the type of developmental errors children make (Ingram, 1991).

One study of five children learning Quiché, a Mayan language, suggested that their early phonetic inventories included sounds (e.g. /ʧ, l/) not acquired until later by English-speaking children, i.e. the order of acquisition differed (Pye, Ingram & List, 1987). Mowrer & Burger's (1991) study of 70 Xhosa-speaking children aged 2;0 to 6;0 found that their subjects mastered the 20 phonemes held in common by Xhosa and English earlier than an English-speaking control group did, and earlier than English-speaking children reported in the literature. The Xhosa-speaking children had mastered 31 of the 41 consonants of their language by three years of age, including some affricates (e.g. /ts, ʧ/) and clicks. However, those sounds acquired last and those most frequently misarticulated by Xhosa-speaking children e.g. /s/ /ʃ/ /r/ are the same phonemes English, German and Swedish children find difficult (Mowrer & Burger, 1991). The Xhosa-speaking children made half the number of errors made by the English speaking group, but the two groups were shown to use similar substitution patterns for affricates and liquids in a taxonomic analysis.

Both groups of researchers interpreted their data as providing evidence against the age of acquisition of phonemes reflecting degree of difficulty of articulation (e.g. Olmsted, 1971). However, their wider interpretations differed. Mowrer & Burger (1991) concluded that their data supported the notion of phonological universals, i.e. 'systematic patterns of speech sounds crosslinguistically' (Ohala, 1980: 181), although they noted the unexplained early acquisition of phonemes. Pye *et al.* (1987) interpreted their data as demonstrating the effect of the ambient language on rate and order of acquisition. They argued that a consonant's rate and order of acquisition will be determined by its functional loading, i.e. its importance within a phonological system of a particular language in terms of its frequency of oppositional occurrence.

Other studies have described the pattern of errors exhibited by children learning languages other than English in terms of phonological processes rather than phonemes. In his study of Swedish children, Magnusson (1983) reported the use of phonological processes such as cluster reduction that are also reported for children learning English, Czech, French & Spanish (Locke, 1983). Similarly, Bortolini & Leonard's (1991) analysis of normally developing and phonologically disordered Italian children (matched for the size of their consonant inventories) revealed the use of processes typically reported for English-speaking children, e.g. assimilation, cluster reduction, weak syllable deletion and liquid deviation. However, a more detailed examination of the children's realization of liquids reflected their awareness of the characteristics of Italian phonology. In languages where /r/ is an alveolar trill, such as Italian, a typical error pattern is to substitute /r/ with /l/, whereas English-speaking children predominantly realise /r/ as /w/ (Smith, 1973). Bortolini & Leonard (1991) explain this crosslinguistic difference in terms of the highly restricted use of /w/ in Italian and the differences between the phonetic characteristics of /r/ in English and Italian, noting also that the substitution patterns exhibited never violated the phonotactic rules of Italian. They concluded that the errors made by phonologically disordered and normally developing Italian-speaking children revealed 'sensitivity to the phonetic characteristics of the phonemes of Italian as well as to the types of sounds in the language that might serve as reasonable substitutes' (Bortolini & Leonard, 1991: 1).

Locke (1983) compared published reports of developmental phonological patterns from a range of languages. While Locke (1983: 71) concluded that 'children learning different languages display many similar sound patterns', he also noted language specific differences. One plausible way of accounting for this apparent contradiction is in terms of Smith's (1973) proposal that phonological rules implement major strategies or processes.[1] These processes are listed below, with one example of a realization rule that implements each function:

Consonant harmony or assimilation: /l, r, j/ are neutralized as /l/ when they are the only consonants in the word, e.g. [lɛloʊ] *yellow*;
Consonant cluster reduction: /l, r, w, j/ delete postconsonantally, e.g. [bu] *blue*;
Systemic simplification: fricatives and affricates are realised as plosives, e.g. [tɪp] for *ship* and *chip*.

For English-speaking children, the number and type of realization rules implementing these strategies varies according to their level of phonological development, which is loosely related to chronological age and level of cognitive development (Macken & Ferguson, 1983). Ferguson & Farwell (1975) studied the acquisition of phonology of three children and made the observation that each of the three children exhibited a unique path of development with individual preferences and idiosyncratic phonological

[1] Smith (1973) proposed four functions: those described above and a fourth: 'grammatical simplification'. This function was implemented by only one rule, which may have been idiosyncratic to the subject of Smith's case study. Dodd (1975) found no evidence for this strategy in a longitudinal study of phonological acquisition in five children.

rules. However, most children learning English share similar sets of phonological rules and apply them consistently (Aitchison, 1987).

Children learning languages other than English may also adopt the same general strategies of assimilation, cluster reduction and systemic simplification, but the way in which those strategies are implemented in terms of realization rules might vary according to the phonetic and phonological structure of the specific language being learned. Evidence for or against such an explanation is sparse because of the dearth of crosslinguistic studies focusing on phonology. Slobin's (1985) major contribution to the crosslinguistic study of language acquisition contains virtually no mention of developmental phonological errors. Other studies have only presented taxonomic data (e.g. Mowrer & Burger, 1991). There is a need, then, for descriptions of the phonological acquisition of children learning languages other than English. One language that has received little research attention is Cantonese.

In 1970, Cantonese was spoken by 37·5 million people in China (Hashimoto, 1972) as well as by five million people in Hong Kong and by large immigrant populations in Australia, Britain, Canada and the United States of America. Cantonese phonology differs from that of English in a number of important ways (see Table 1). It is a tone language where the change in tone of a syllable can lead to a change of meaning. There are six contrastive tones: high level, high rise, mid level, low fall, low rise, low level; and three entering tones that are allotones of the three level tones. Cantonese has 17 initial consonants and two syllable-initial consonant clusters, eight final consonants and eight vowel phonemes. The syllable structure of Cantonese is relatively simple: there are two syllabic nasals /m/ and /ŋ/, and all other syllables have the following structure: [[C]-[Glide]]-V-[C/Glide]. The number of segments can vary from one to four with a vowel being an obligatory segment.

There have been three previous studies on aspects of phonological acquisition by Cantonese-speaking children. J. K.-P. Tse (1978) carried out a 30-month longitudinal study of his son's acquisition of tone, showing that the perception of tonal contrasts precedes their production. He divided the acquisition of tone production into three stages: in Stage 1 (1;2–1;4), high level and low falling tones were acquired; in Stage 2 (1;5–1;8), mid level, high rising and three entering tones; and in Stage 3 (1;9), low rising and low level tones. Thus, tone appears to be mastered very early, and well before segmental phonology. Similar findings for the acquisition of tone were made by S.-M. Tse (1982). He collected six speech samples from a girl aged 1;7 to 2;8, plus cross-sectional samples from two children aged 1;8 and 2;0. These samples were analysed to describe the children's phonological processes; however, no consistent patterns emerged. The samples were also analysed to describe the children's phonetic inventories. At least two of the subjects had

TABLE 1. *Differences between Cantonese and English phonology*

	Cantonese	English
Tones	6 contrasting, 3 entering	None
Initial consonants	p pʰ t tʰ k kʰ m n ŋ f s h w j l ts tsʰ	p b t d k g m n θ ð f v s z ʃ ʒ h w j l r ʧ, ʤ
Clusters	kw kʰw	p b t d k g θ + l r j s + p t k l w s + p t k + l r j w
Final consonants	p t k m n ŋ w j	p b t d k g m n ŋ θ ð f v s z ʒ ʃ ʧ ʤ l r
Vowels	i ɐ u œ ɔ o ɛ a	i ɪ ɛ æ ʌ a ɒ ɔ ʊ u ɜ ə eɪ oʊ aɪ aʊ ɔɪ ɪə ɛə ɔə ʊə
Syllable structure	[[C]-[G[a]]]-V-[C/G]	$[C_{0-3}]$-V-$[C_{0-4}]$

[a] G = glide.

acquired the following segments – /m, n, ŋ, p, t, k, ts, tsʰ, s, h, j/. Repertoires for English-speaking children of the same age include no affricates, but the size of the consonant inventory is about the same – /m, n, p, b, t, d, k, g, f, s, h, w/ (Ingram, 1989). The Cantonese-speaking children used unaspirated voiceless stops whereas English-speaking children commonly aspirate voiceless stops. Aspiration is a contrastive feature in Cantonese, but not in English. The fact that Cantonese-speaking children do not use aspirated stops while English-speaking children do at the same age, may imply that some aspects of phonological acquisition are not universal, but are influenced by the phonological structure of the language being learned.

In contrast A. C.-Y. Tse's (1991) longitudinal case study of a Cantonese-speaking boy aged 1;3–2;6 found evidence for universal trends in the sequence of phoneme acquisition. The types of phonological error identified included assimilation, cluster reduction and systemic simplification (e.g. stopping, fronting). Most of these errors can be found in the developmental errors of English-speaking children. However, while A. C.-Y. Tse (1991) concluded that his findings confirmed Jakobson's (1941/68) law of implicature, he also identified the use of some phonological rules usually associated with disorder in English-speaking children, e.g. affrication of fricatives.

These case studies suggest that the types of error made by children acquiring Cantonese as their first language are similar to those made by children learning English, despite the two languages' very different phonological structure (i.e. tones, aspiration, syllable structure etc.). However, the number and the age ranges of the children studied were limited. The study reported here describes the phonological systems of children aged 2;0–6;0 in terms of their tone, vowel and consonant inventories, and their use of phonological rules. It was predicted that the pattern of phonological errors would reflect Smith's (1973) processes: assimilation, cluster reduction and systemic simplification; but that how these processes were implemented would be influenced by the structure of Cantonese phonology. Specifically:

at first, all sounds will be de-aspirated, since markedness theory predicts that the unmarked member of a pair is produced before the marked member (Chomsky & Halle, 1968);
tones will be acquired early, since this aspect of Cantonese phonology carries a high functional load (Pye *et al.* 1987);
consonant clusters will be reduced: given that /kw/ and /k^hw/ are the only Cantonese consonant clusters, it is more likely that the /$k^{(h)}$/ will be the member deleted rather than the /w/, since many more words in the early vocabularies of Cantonese children begin with /k/ than /w/, i.e. reducing the cluster by deleting /k/ promotes intelligibility by reducing homonymy (Leonard, Schwartz, Allen, Swanson & Loeb, 1989).

METHOD

Subjects: cross-sectional study

The subjects were 268 Cantonese-speaking children who attended child-care centres or kindergartens in Hong Kong. The total group consisted of children in eight six-month age bands between two and six years: 2;0–2;5 ($N = 26$); 2;6–2;11 ($N = 33$); 3;0–3;5 ($N = 38$); 3;6–3;11 ($N = 33$); 4;0–4;5 ($N = 34$); 4;6–4;11 ($N = 34$); 5;0–5;5 ($N = 34$); and 5;6–5;11 ($N = 36$). Approximately equal numbers of boys and girls were tested in each age group. Children from a range of socio-economic backgrounds were assessed by sampling in four different areas of Hong Kong, Kowloon and the New Territories. All children were acquiring Cantonese as their first language and teachers reported that none had any intellectual or hearing impairment, nor any history of a speech or language disorder.

Materials

Fifty-seven words were selected for inclusion in a picture-naming test (see Appendix 1). These words sampled two examples of all Cantonese vowels, tones, and initial and final consonants. At least one representative of each class of medial sounds was also sampled. The words chosen were names of common objects likely to be known by preschool children. High-quality colour photographs were taken of real objects, and each four-by-five-inch photograph was glued onto a separate white card and then laminated. To sample the pronunciation of words in continuous speech, sets of five photographs illustrating two narrative sequences were prepared. The five-by-seven-inch photographs were glued onto separate cards and were presented one after the other. One narrative concerned a trip to the park and the other activities related to getting ready for school.

Procedure

Subjects were tested individually in a quiet room at their child-care centre or kindergarten by one of three Cantonese-speaking examiners. The examiners were speech therapy students who had completed two years' tertiary training in phonetics; they were skilled in collecting speech data from young children. Each testing session took about 15–20 minutes and was audiotaped using a Sony TCM-1000A recorder fitted with a condenser microphone. The children were first asked to name the 57 pictures. If they did not know the name of a picture, the examiner gave semantic cues. If the children were still unable to name the picture they were asked to imitate the examiner's naming, and this was coded on the response sheet. To elicit continuous speech, each subject was asked to retell the stories told by the examiners using the pictures as a memory aid. The examiners recorded the children's responses using narrow phonetic transcription during the testing session. Audio-recordings of 27 of the children's sessions were retranscribed by the same examiner to check intra-rater reliability, and by another examiner for inter-rater reliability. Reliability of transcription for individual phonemes was computed and is shown in Table 2. A child was judged to have acquired a phoneme if

TABLE 2. *Intra- and inter-transcriber reliability for Cantonese phonemes*

% Agreement	Intra-transcriber	Inter-transcriber
100	SIWI: p pʰ t tʰ k kʰ m f s h l w j ts tsʰ kw kʰw SFWF: p t k m ŋ w j SIWW: p pʰ t tʰ k kʰ m n ŋ f s h l w j ts tsʰ All vowels, diphthongs and tones	SIWI: p pʰ t tʰ k kʰ m f s h l w j ts tsʰ kʰw SFWF: t k m n ŋ w j SIWW: p pʰ t tʰ k kʰ m n ŋ f s h l w j ts tsʰ All vowels, diphthongs and tones
95–99	SIWI: n SFWF: n SIWW: clusters	SIWI: n kw SFWF: p
90–94	SIWI: ŋ	SIWI: ŋ SIWW: clusters

SIWI, syllable-initial word-initial; SFWF, syllable-final word-final; SIWW, syllable-initial within words.

TABLE 3. *Overview of speech errors made in the cross-sectional study*

Age	2;0–;5	2;6–;11	3;0–;5	3;6–;11	4;0–;5	4;6–;11	5;0–;5	5;6–;11
Total errors	501	372	210	158	82	105	27	29
Mean error	19·3	11·3	5·5	4·8	2·4	3·1	0·8	0·8
% SI errors	89·8	76·3	88·6	88·0	82·9	78·1	48·2	75·9
% SF errors	5·0	17·0	8·0	8·2	15·9	10·5	37·0	24·1
% Vowel errors	4·4	5·1	2·9	3·8	1·2	8·6	14·8	0
Unclassifiable	0·8	1·6	0·5	0	0	2·8	0	0

Unclassifiable: those errors that could not be accounted for by the phonological processes listed in Table 7, e.g. lisps; one-off errors /f/-> [pw].
SI, syllable initial; SF, syllable final.

it was produced correctly twice in the single-word naming test. If only one of these two items was correct, the continuous speech from story retelling was examined to check whether the child had spontaneously produced the phoneme correctly in a second example. The continuous speech data are not otherwise reported in this paper.

Subjects: longitudinal study

An additional four children took part in a study that focused on the acquisition of tones. Two girls and two boys were assessed longitudinally between the ages of 1;2 and 2;0 at fortnightly intervals. The children had been born at full term, were healthy and had reached developmental milestones at the appropriate chronological ages. None had any hearing impairment. Cantonese was the primary language spoken in their homes, where the language samples were recorded.

Procedure

Each 45 minute visit consisted of a period of free play, then play with specific toys and naming of pictures in order to sample all tones. The data were audiotaped using a high-quality tape-recorder and microphone and transcribed immediately after the session. Reliability checks by another transcriber on 10% of the data, covering the total age range, revealed an agreement of 90%.

RESULTS

Table 3 gives an overview of the data from the large cross-sectional study. The number of errors declined over the age span, most of these errors affecting consonants in syllable-initial position. The proportion of vowel and syllable final errors was small in comparison, but tended to rise across the age span as the number of syllable initial errors decreased. The number of unclassifiable errors (i.e. errors not able to be described by the phonological rules listed in Table 7) remained low for all age groups except the children aged 4;6–4;11.

Age of emergence of syllable-initial and -final consonant phonemes

A phoneme was judged acquired if 90% of the children in the sample produced the phoneme correctly in at least two words. Table 4 summarizes the data. Both girls and boys acquired all 17 syllable-initial consonants and the two clusters by 5;0, and all syllable-final consonants by 4;6. The girls'

TABLE 4. *Age of emergence of syllable-initial and -final consonant phonemes (criterion: 90% of subjects)*

	Male		Female	
Age	Initial	Final	Initial	Final
2;0	n ŋ	j w	p m n h w j	j w
2;3			t	
2;6	p t j		k	
2;9		m	ŋ l	p k m
3;0	m w	n	f	
3;3	k	p ŋ	p^h	
3;6	h		k^h	
3;9		t k	kw	
4;0	p^h t^h k^h ts kw l		t^h	ŋ
4;3	f ts^h		ts	n
4;6	s		s	t
4;9			k^hw	
5;0	k^hw		ts^h	

TABLE 5. *Comparison of age of phoneme acquisition: Cantonese and English*

	Cantonese		English
Age	90% Criterion	75% Criterion	75% Criterion[a]
2;0–2;6	n p t j	p t m n ŋ h j k l w	n p m h
2;6–3;0	m w ŋ	f s p^h ts	t j w ŋ k d b f
3;0–3;6	h k	t^h k^h ts^h	g s r l
3;6–4;0	l p^h t^h k^h		ʃ ʧ
4;0–4;6	f s ts		ð ʒ
> 4;6	ts^h		ʤ θ v z

[a] Prather *et al.* (1975).

acquisition initially proceeded more rapidly than that of the boys, but by four years each had mastered 15 syllable-initial phonemes. Unaspirated plosives and nasals were acquired before fricatives and affricates; unaspirated phonemes were acquired before their aspirated partners. The age of acquisition of phonemes in Cantonese was compared to that of children learning English (see Table 5). Both groups first acquired nasals, glides and bilabial and alveolar stops followed by /h/ and /k/. Aspirated plosives, affricates and voiced fricatives were acquired later. However, Cantonese-speaking children appeared to complete their phoneme repertoire more quickly than English-speaking children (comparison of Cantonese and English data using 75% criterion). Seventy-five percent of Cantonese children completed their acquisition by 3;6, whereas 75% of English-speaking children do not complete their phoneme acquisition until after four years according to

TABLE 6. *Percentage correct production of phonemes and clusters by Cantonese-speaking children (2;0–6;0 years, N = 268)*

Initial consonant	% Correct	Initial consonant	% Correct	Final consonant	% Correct
p	99·6	l	94·6	j	99·4
j	99·6	f	93·8	p	99·2
n	99·2	k^h	92·3	w	98·6
ŋ	99·0	p^h	90·9	k	98·0
m	98·6	ts	90·7	m	97·8
w	98·2	s	89·5	n	96·8
t	97·6	t^h	89·1	t	95·2
k	97·2	ts^h	84·1	ŋ	91·7
h	95·2				

TABLE 7. *Acquisition of tone*

	Child			
Age	A	B	C	D
1;4	1, 3	1, 3	1, 3	1, 3
1;5	1, 3	1, 3	1, 3	1, 3
1;6	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3
1;7	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3, 7, 8, 9
1;8	1, 2, 3, 6, 7, 8, 9	1, 2, 3, 6, 7, 8, 9	1, 2, 3, 4, 5, 7, 8, 9	1, 2, 3, 7, 8, 9
1;9	1, 2, 3, 6, 7, 8, 9	1, 2, 3, 6, 7, 8, 9	1, 2, 3, 4, 5, 7, 8, 9	1, 2, 3, 7, 8, 9
1;10	1, 2, 3, 6, 7, 8, 9	1, 2, 3, 6, 7, 8, 9	1, 2, 3, 4, 5, 7, 8, 9	Complete
1;11	Complete	1, 2, 3, 6, 7, 8, 9	Complete	Complete
2;0	Complete	Complete	Complete	Complete

Tone Code: 1, high level$_{(55)}$; 2, high rise$_{(35)}$; 3, mid level$_{(33)}$; 4, low fall$_{(21)}$; 5, low rise$_{(23)}$; 6, low level$_{(22)}$; 7, high entering$_{(5)}$; 8, mid entering$_{(3)}$; 9, low entering$_{(2)}$.

Prather, Hedrick & Kern (1975), and after six years according to Templin (1957) and Olmsted (1971). The phonemic repertoires of three children are outlined in Appendix 2.

Another way of determining the order of phoneme acquisition is to calculate the percentage correct production of individual phonemes for the whole group. Locke (1983) argued that it is possible to infer the order of acquisition of phonemes in a language by examining these percentages: those sounds produced with high percentage scores are assumed to be acquired early. Comparison of Tables 5 and 6 shows some minor differences between the two ways of determining the order of phoneme acquisition. For example, using the 90% criterion of production, /t/ was judged acquired at 2;0–2;6, although it had a lower percentage score than /m/ and /w/, which were not acquired until six months later. However, all three phonemes gained very high percentage scores (i.e. greater than 97·6%). One advantage, however, of reporting the percentage scores is that it allows comparison of other languages reported by Locke (1983), who reviewed data from, among others, Japanese, Italian and Swedish (see Appendix 3). Phonemes acquired early in these languages, and in Cantonese, are nasals, glides and front stops. Phonemes reported to be acquired late are fricatives (apart from /f/) and affricates. Nevertheless, there were some differences. For example, /p/ in English is generally aspirated and is acquired early by English-speaking children, whereas the Cantonese-speaking children acquired unaspirated /p/ before its aspirated counterpart. This finding may reflect phonological differences between the two languages. Alternatively what was perceived by researchers as aspirated /p/ in English may have been an unaspirated allophone (Smith, 1973). However, given that the languages compared come from four different language families (i.e. Sino-Tibetan, Altaic, Romance and Scandinavian), it seems unlikely that the similarities observed for order of acquisition can be solely attributed to the languages having similar phonological systems. Rather the similarities would seem to reflect a tendency towards a universal order of phoneme acquisition.

Vowels

All vowels were being used contrastively by 90% of the children in the youngest age group and all other age groups. Only 15 children (5·6%) made two or more vowel errors, the total number of vowel errors being 67, representing only 4·5% of total errors. Although there were few errors, there seemed to be one consistent pattern: vowels were sometimes changed to harmonize with the adjacent consonants, e.g. [kɔk]/kœk/, accounting for 29% of the vowel errors made. The other 40 vowel errors showed no consistent error pattern.

Tones

Only two children in the cross-sectional study made tone errors, one four-year-old made two and a five-year-old made three. That is, by two years of age most children had mastered tonal contrasts. To gain information concerning the acquisition of tone, four children were assessed longitudinally between the ages of 1;2 and 2;0. A tone was judged to have been acquired when it was used contrastively on at least 50% of opportunities or correctly on 90% of opportunities. Table 7 summarizes their acquisition of tone. All four children showed a similar pattern of order and rate of acquisition. They all first acquired two of the three level tones (high level and mid level tones) followed by the high rise tone and then the three entering tones. Two of the children then acquired the low level tone before the low fall and low rise tones, whereas child C showed the opposite pattern and child D acquired these three tones simultaneously. All children had completed their acquisition of tone by age 2;0.

TABLE 8. *Percentage of children using phonological rules affecting syllable-initial consonants*

	Age							
	2;0–;5	2;6–;11	3;0–;5	3;6–;11	4;0–;5	4;6–;11	5;0–;5	5;6–;11
No. errors	3·8	6·1	23·7	24·2	50	41·2	70·6	75
Structural simplification								
Assimilation	38·5	21·2	7·9	6·1	—	5·9	—	—
Cluster reduction	76·9	39·4	26·3	24·2	2·9	8·8	2·9	—
/h/ deletes	11·5	6·1	5·3	3·0	2·9	—	—	—
IC Deletion	7·7	9·1	—	—	2·9	—	—	—
Systemic simplification								
Stopping	61·5	36·4	15·8	15·2	5·9	8·8	2·9	2·7
Fronting	46·2	24·2	10·5	9·1	8·6	2·9	2·9	2·7
De-aspiration	57·7	33·3	31·6	9·1	8·6	—	—	2·7
Affrication	42·3	18·2	7·9	6·1	8·8	2·9	2·9	2·7
De-affrication	3·8	18·2	5·3	3·0	—	8·8	2·9	2·7
Frication	7·7	3·0	5·3	—	—	—	—	—
Aspiration	7·7	—	2·6	6·1	8·8	5·9	—	—
Gliding	7·7	3·0	2·6	3·0	2·9	5·9	—	—
Backing	3·8	3·0	5·3	3·0	2·9	5·9	—	—

Syllable-initial consonant errors

Most errors affected syllable-initial consonants (see Table 3). These errors could be classified into three patterns: assimilation, cluster reduction and systemic simplification errors. Table 8 lists the proportion of children in each age group who made more than two errors exemplifying phonological rules implementing these strategies. Inspection of the table shows that many children in the two youngest age groups used the following strategies: assimilation; cluster reduction; and systemic simplification rules which governed stopping, fronting, de-aspiration and affrication. Cluster reduction, stopping and de-aspiration remained important error patterns for the three-year-old children. From four years of age, less than 10% of children used any one error strategy consistently.

Each of the processes used by more than 10% of the sample at more than one age band is described in detail below.

(*i*) *Assimilation*. There were 51 errors that were attributed to the process of assimilation. Forty-seven of these (92%) were examples of a syllable initial alveolar being realized as a velar, in the presence of a syllable final velar (e.g. [k^hɔŋ$_2$])/t^hɔŋ$_2$/). The other assimilation errors were: [pɐm$_2$]/jɐm$_2$/; [ŋaŋ$_5$]/ŋan$_5$/; [kɛŋ$_2$]/pɛŋ$_2$/ (twice).

(*ii*) *Cluster reduction*. While the younger children's most common realization of/$k^{(h)}$w/was [$k^{(h)}$], if the /k/ was fronted it was more likely to be realized as a [p] than as a [t] (e.g. [pa] /kwa/), whereas a singleton /k/ was usually fronted to [t], and never to [p] (e.g. [tɐj]/kɐj/). Thus, although the /w/ was deleted, many children took account of its place of articulation in choosing how to mark the cluster. The oldest group of children to reduce clusters consistently also often marked the level of aspiration of the target cluster by realizing /kw/ as [f] but /k^hw/ as [$p^{(h)}$].

(*iii*) *Stopping*. Eighty-eight percent of the children's stopping errors resulted in /f, s, ts, ts^h/ being realized as a plosive at their place of articulation. The children realized the unaspirated continuant /ts/ as an unaspirated /t/ whenever it was stopped. When the youngest children stopped the aspirated continuant /ts^h/, it was realized as the unaspirated plosive /t/ 76% of the time. However, when children aged 2;6–3;5 stopped the aspirated continuant /ts^h/, it was realized as the aspirated plosive /t^h/ 81% of the time; with only 19% /t/ substitutions. The older age groups made too few stopping errors to allow meaningful analysis.

(*iv*) *Fronting*. The two phonemes affected by the process of fronting were /k/ and /k^h/. When they occurred in CV(C) syllables, both were always realized as /t/ by the younger children; however, as the children suppressed the de-aspiration process, /k^h/ was substituted by /t^h/. The pattern of fronting was different when /k/ and /k^h/ occurred in clusters (see above).

TABLE 9. *Rules affecting initial consonants used by more than 10% of children*

	% Frequency	Targets	Most common error forms[a]
2;0–2;5			
Assimilation	43	—	SI alveolars harmonize with SF velars
Cluster reduction	81	kw k^hw	k^hw: [$k^{(h)}$] 42 % [$p^{(h)}$] 27 % [t] 15 % [f] 12 %
			kw: [k] 50 %, [p] 31 % [t] 10 % [w] 4 % [f] 2 %
Stopping	59	f s ts ts^h	Same place 95 %
Fronting	76	f k k^h kw k^hw	$k^{(h)}w$: [p] 71 % [t] 29 %; $k^{(h)}$: [t] 92 % [ts] 8 %
De-aspiration	62	p^h t^h k^h ts^h k^hw	[p t k ts kw]
Affrication	68	s	[$ts^{(h)}$]
/h/ deletes initially	100	/h/	—
2;6–2;11			
Assimilation	67		SI alveolars harmonize with SF velars
Cluster reduction	80	kw k^hw	k^hw: [$k^{(h)}$] 54 % [$p^{(h)}$] 25 % [t] 21 %
			kw: [k] 42 % [p] 33 % [t] 11 % [w] 11 % [f] 11 %
Stopping	44	f s ts ts^h	Same place 96 %
Fronting	57	f k k^h kw k^hw	$k^{(h)}w$: [p] 54 % [t] 46 %; $k^{(h)}$: [$t^{(h)}$] 100 %
De-aspiration	40	p^h t^h k^h ts^h k^hw	[p t k ts kw]
Affrication	96	s	[$ts^{(h)}$]
Deaffrication	60	ts ts^h	[s]
3;0–3;5			
Cluster reduction	78	kw kw^h	k^hw: [$k^{(h)}$] 47 % [$p^{(h)}$] 37 %
			kw: [k] 55 % [p] 25 % [f] 10 %
Stopping	38	f s ts ts^h	Same place 68 %
Fronting	54	f k k^h kw k^hw	$k^{(h)}w$: [p] 58 % [t] 17 % [f] 25 %; $k^{(h)}$: [$t^{(h)}$] 100 %
De-aspiration	38	p^h t^h k^h ts^h k^hw	[p t k ts kw]
3;6–3;11			
Cluster reduction	50	kw k^hw	k^hw: [$k^{(h)}$] 30 % [$p^{(h)}$] 50 % [f] 20 %
			kw: [k] 30 % [p] 20 % [f] 50 %
Stopping	53	f s ts ts^h	Same place 93 %

[a] The number of times a particular error form occurs as a percentage of the number of errors for that target in the category, e.g. the number of times /$k^{(h)}w$/ is realized as [p] is divided by the total number of 'fronting' errors involving /$k^{(h)}w$/ × 100.

(*v*) *De-aspiration.* De-aspiration was a prominent process in the Cantonese-speaking children's data (see Table 8). The process often co-occurred with other processes such as stopping and fronting. The Cantonese-speaking children's use of de-aspiration is significant crosslinguistically because English-speaking children use the aspirated series.

(*vi*) *Affrication.* More than 10% of children under the age of 2;11 affricated fricatives (e.g. [tsy]/sy/). The Cantonese-speaking children did not acquire fricatives or affricates as part of their phonemic repertoire until they were aged at least 2;6. The error pattern of affrication was unexpected, since 42% of the youngest children and 18% of the 2;6–2;11 age band, used [ts] to mark /s/, despite /ts/ not being part of their phonemic repertoire (i.e. neither /ts/ nor /tsʰ/ were used correctly, typically being realized as a stop). Ninety-one percent of the affrication errors involved /s/ being realized as [ts], while the others involved affrication of /t⁽ʰ⁾/ and /k⁽ʰ⁾/.

Some error patterns were produced by a small number of children, e.g. frication, backing, initial consonant deletion, aspiration and gliding. Other error patterns appeared to be rules used by a particular age-group, e.g. de-affrication, /h/ deletes initially. Those error patterns used by more than ten percent of children in any age-group are listed in Table 9 with their percentage frequency of application (i.e. number of occurrences per number of opportunities), the phonemes affected and the most common error forms.

Syllable-final consonants

Only a relatively small proportion of the total number of errors were made on syllable-final consonants. Only 37 children (13·8%) made more than two errors on syllable-final consonants, resulting in 159 errors (10·7% of total errors). Three rules accounted for all errors: fronting (e.g. [pɛn] /pɛŋ/), accounting for 28·9% of syllable-final errors; backing (e.g. [mɐk] /mɐt/), 34·6%; and final consonant deletion (e.g. [tsu] /tsuk/), 36·5% of errors. Fifteen percent of the 2;0–2;6 group and 21% of the 2;6–2;11 group deleted syllable-final consonants.

DISCUSSION

The results indicate that the Cantonese-speaking children's acquisition of phonemes followed a similar order to that reported for English-speaking children, although the rate of acquisition was more rapid. These findings are in agreement with the results of S.-M. Tse's (1982) and A. C.-Y. Tse's (1991) case studies of children acquiring Cantonese. The findings also add to evidence from children learning Xhosa (Mowrer & Burger, 1991) and Quiché (Pye *et al.* 1987) that English-speaking children may be relatively slow to complete the acquisition of their consonant phoneme inventory. Ingram (1989) suggests that the rate and order of the acquisition of consonants are determined by their functional load, where functional load is measured in

TABLE 10. *Comparison of the phonological structure of English, Cantonese and Xhosa*

	English	Cantonese	Xhosa[a]
Vowels and diphthongs	21 + 5 trithongs	8	7
Consonants	24 + 49 clusters	17 + 2 clusters	41 few clusters
Syllable/word structure	$[C_{0-3}]$-V-$[C_{0-4}]$ Polysyllabic	[[C]-[G]-V-[C/G] Mostly monosyllabic	Mostly CV, VC Polysyllabic
Tones	None	9	9
Stress	Complex	Simple	Simple/regular

[a] Cube (1950).

terms of the number of oppositions or minimal pairs in which a consonant occurs in a child's language environment. While variation in the order of acquisition of consonants might be elegantly explained in this way, it is a less plausible explanation for rate of acquisition of a phoneme inventory in a particular language. Ingram's (1989) way of determining functional load does not include other aspects of phonology that might contribute, relatively, to the functional loading of consonants: vowels, syllable structure, stress and tone. Table 10 contrasts these aspects of the phonologies of English, Cantonese and Xhosa.

The phonology of English differs from that of the other languages described in Table 10 in a number of important ways. English has more than twice the number of vowels than the other languages. The role of the vowel in English phonology is important: they are numerous, they have distinctive syllabic value and they are oppositional, e.g. *hat*, *hot*, *heart*, *heat*, *hit*, *hurt*, *hut*, *height*, *hate*; *spin*, *spoon*, *spun*, *spurn*, *span*, *spine*, *Spain* (Gimson, 1989). Vowels therefore carry a heavy functional load in English. The number of consonants also varies across these three languages. English stands out as having a large number of consonant clusters and a more complex syllable structure. While Xhosa contains many polysyllabic words, many of the examples listed by Mowrer & Burger (1991) contain in-built consonant and syllable harmony, with most consonants being intervocalic, e.g. *utata* 'father', *duda* 'dance', *unopopi* 'doll', *igogogo* 'paraffin tree'. Stress in English is complex (Gimson, 1989), whereas it is regular in Xhosa, occurring on the penultimate syllable of all words except ideophones, where the first syllable is stressed. In Cantonese there is a correlation between stress and tone, higher tones receiving greater stress (Hashimoto, 1972). Tone carries a functional load in Xhosa and Cantonese, but not in English.

Comparison of the phonology of the three languages suggests that the concept of functional load might be usefully expanded to include consideration of other aspects of a language's phonology besides consonants. Their contribution to differentiating words seems to vary across languages. In Xhosa, consonants appear to be the most important aspect of the phonology differentiating words. If this is accepted, then it seems logical to assume that it would be important for children to master consonants early so as to maximize intelligibility. Cantonese words are mainly monosyllables that have a relatively simple syllabic structure, and there are only eight vowel phonemes. Thus, tones plus consonants carry a heavy functional load and would need to be acquired early. In English, the burden of distinctiveness between words is carried by vowels, syllable structure and stress as well as consonants. That is, the functional loading of consonants seems relatively less in English than in the other languages examined. It may be that the rate of acquisition of consonants, vowels, syllable structure, stress and tones is influenced by their relative contributions to the burden of carrying meaning. The worth of this hypothesis awaits further research, which might test predictions, derived from the structure of a language's phonological structure, about rate of acquisition of different aspects of phonology.

The study reported here shows that children acquiring Cantonese make few vowel and tone errors, and seem to have mastered these aspects of their system by two years. Similar findings were reported by J. K.-P. Tse (1978), S.-M. Tse (1982) and A. C.-Y. Tse (1991). All studies report that children acquire level tones before those with contour. The contrast first established was between the high level and another level tone, followed by the contrast between the high level and the high rise tone. The entering tones were acquired before the other contour tones and the remaining level tone. Probably the most important reason why children acquire tonal contrasts so early in their phonological acquisition is that in Cantonese, many words are distinguished by their tones, e.g. /ji_1/ 'aunty', /ji_2/ 'chair', /ji_3/ 'meaning', /ji_4/ 'move', /ji_5/ 'ear', /ji_6/ 'two'. Infants have been shown to be capable of perceiving prosody as early as six weeks of age, and of producing babbled intonation patterns that resemble those of their native language from about six months (Crystal, 1986), so it is perhaps not surprising that the suprasegmental aspects of Cantonese phonology can be mastered so early and so rapidly.

The consonant error patterns identified fit well with Smith's (1973) processes of assimilation, consonant cluster reduction and systemic simplification. The use of assimilation was most apparent in the errors of the two-year-old children, but faded as a production strategy used by the older children. A. C.-Y. Tse's case showed a similar pattern: he reduplicated syllables before two years, and assimilation increased as reduplication faded during the second year. Most cases of assimilation involved final velar consonants influencing the preceding consonant, e.g. [kuk] /tsuk/; [kɔŋ] /$t^hɔŋ$/. However, assimilation may not be as important an error pattern in

Cantonese as it seems to be in English, simply because so many Cantonese words are open syllables, and the range of consonants occurring in syllable-final position is small.

Cluster reduction was an important error pattern for children aged 2;0–3;0. We had predicted that children would be more likely to delete the /k$^{(h)}$/ in /k$^{(h)}$w/ clusters, because fewer words begin with /w/ than with /k/ in children's early vocabularies, and the maintenance of /w/ would reduce homonymy. Only two children (one three-year-old and one four-year-old) consistently used this way of reducing clusters. However, the way in which the Cantonese-speaking children realized clusters showed two subtle patterns not found in children acquiring English.

(*i*) While the younger children's most common realization of /k$^{(h)}$w/ was [k$^{(h)}$], if the /k/ was fronted it was more likely to be realized as a [p] than as a [t] (e.g. [pa] /kwa/), whereas a singleton /k/ was usually fronted to [t], and never to [p] (e.g. [tɐj] /kɐj/). A similar pattern of development is reported by A. C.-Y. Tse (1991) in his case study. Thus, although the /w/ was deleted, many children took account of its place of articulation in choosing how to mark the cluster. A similar error pattern is NOT reported for English-speaking children: place of articulation of the deleted member does not influence choice of substitute (e.g. [pin] *queen* would be an unusual error).

(*ii*) The oldest group of children consistently to reduce clusters often marked the level of aspiration of the target cluster by realizing /kw/ as [f] but /k^{h}w/ as [p$^{(h)}$]. Although English does not have contrastive aspiration, it does have a voicing distinction which is analogous in that both aspiration and voicing are measurable in terms of voice onset time (VOT). Clumeck, Barton, Macken & Huntington (1981) described the acquisition of the aspiration contrast by a Cantonese-speaking two-year-old boy, using instrumentation to measure VOT. They found that the developmental sequence paralleled that for the voicing contrast in English-speaking children. However, level of voicing does not appear to influence the cluster reduction pattern of English-speaking children, e.g. *trip* and *drip*-> [tɪp] and [dɪp].

The most widely used rules implementing systemic simplification were: velar plosives were realized as alveolars (fronting); and fricatives and affricates were realized as plosives at the same point of articulation (stopping). Both these rules are used by English-speaking children. Cantonese-speaking children also de-aspirated aspirated phonemes in much the same way as English-speaking children initially tend to voice all sounds, i.e. children tend to produce the unmarked member of a pair. However, the effect of Cantonese phonology on the generation of systemic simplification rules was apparent. One rule that was used relatively commonly by two-year-olds, but which is considered unusual in English-speaking children, results in affrication of /s/, e.g. [pa tsi] /pa si/, [tsœj] /sœj/. This pattern was also reported by A. C.-Y. Tse (1991). Affrication was an unexpected error pattern, since English-speaking children acquire affricates later than fricatives, and the most commonly associated developmental error involves stopping, e.g. [tɪp] /chɪp/ (Dodd, 1975). In contrast, while some Cantonese-speaking two-year-olds de-affricated /ts/, e.g. [siw] /tsiw/, affrication of /s/ was much more common. Such errors cannot be accounted for by a phonetic explanation, i.e. variable imprecise articulation, since the substitution patterns were unidirectional. For example, the data indicated that children who used a rule that resulted in /s/ being realized as [ts] did not simultaneously provide examples of de-affrication, i.e. /ts/ -> [s].

Those error patterns used by less than 10% of children can be attributed to a number of sources. Some of the rules, e.g. gliding, may be normal developmental processes that are fading out. A. C.-Y. Tse's (1991) case showed extensive use of gliding before age 2;0. The small number of children continuing to make gliding errors here may comprise those children whose development is a little delayed. Other rules, e.g. de-affrication, may be transient, and the developmental role they play in the acquisition of phonology may be difficult to establish in a cross-sectional study. Some children provided evidence of the use of idiosyncratic rules: e.g. one child realized aspirated plosives as fricatives. This child may have found a temporary and unusual solution to the problem of marking a difference between aspirated and unaspirated sounds. Alternatively, such data might arise from the inclusion of subjects who are phonologically disordered. The incidence of phonological disorder lies between 3 and 10% of the normal population (Enderby & Philipp, 1986). In a subject group of 268, even with careful exclusion criteria, it is likely that some children not identified as having a phonological disorder would have been included, particularly in the younger age groups. Two error patterns in the data might indicate disorder. The deletion of syllable-initial consonants other than /h/, e.g. [i] /si/, has a major effect on intelligibility because many Cantonese words are CV monosyllables, and initial consonant deletion results in words marked only by a vowel and a tone. The realization of syllable-initial consonants at a velar place of articulation, e.g. [koʊ] /toʊ/, also interferes with intelligibility, because /k/ already occurs frequently in syllable-initial positions. Neither of these rules was reported by A. C.-Y. Tse (1991), and a current study of phonologically disordered Cantonese-speaking children suggests that they are associated with disorder (So & Dodd, 1994).

It was predicted that the pattern of phonological errors would reflect Smith's (1973) universal tendencies of assimilation, cluster reduction and systemic simplification, but that the rules used would reflect children's sensitivity to, and understanding of, the structure of Cantonese phonology. In general, the prediction was confirmed. Further evidence that phonological acquisition involves the interaction of linguistic universal tendencies with a language-specific context comes from the emergence of Cantonese-speaking children's consonant phoneme inventories. The order of acquisition followed a generally universal path, but the rate of acquisition was rapid compared to that of English-speaking children, perhaps reflecting the need to maximize intelligibility in a phonology heavily dependent on consonants to mark differences between words.

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APPENDIX 1

Items in the Cantonese Segmental Phonology Test (So, 1991)

1	/ŋan$_5$/ 'eye'	20	/pa$_1$ si$_2$/ 'bus'	39	/tsuk$_7$/ 'porridge'
2	/mɐt$_9$/ 'sock'	21	/ts^{h}in$_1$ ts^{h}ɐw$_1$/ 'swing'	40	/maw$_1$/ 'cat'
3	/lɛj$_2$/ 'pear'	22	/tɪn$_6$ wa$_2$/ 'telephone'	41	/fu$_3$/ 'trousers'
4	/haj$_4$/ 'shoe'	23	/min$_6$ paw$_1$/ 'bread'	42	/ts^{h}œj$_1$/ 'blow'
5	/nɐw$_2$/ 'button'	24	/puj$_1$/ 'cup'	43	/jip$_9$/ 'leaf'
6	/pɛŋ$_2$/ 'biscuit'	25	/ŋɐw$_4$ naj$_5$/ 'milk'	44	/wɔŋ$_4$/ 'yellow'
7	/sɐw$_2$/ 'hand'	26	/ap$_8$/ 'duck'	45	/t^{h}ɔŋ$_2$/ 'sweet'
8	/k^{h}ɐm$_4$/ 'piano'	27	/sœj$_2$/ 'water'	46	/ts^{h}ɛ$_1$/ 'car'
9	/wun$_2$/ 'bowl'	28	/kœk$_8$/ 'leg'	47	/sy$_6$/ 'tree'
10	/tsiw$_1$/ 'banana'	29	/kɐw$_2$/ 'dog'	48	/jɐm$_2$/ 'drink'
11	/kɐj$_1$/ 'pen'	30	/tɐŋ$_1$/ 'lamp'	49	/syt$_8$ kow$_1$/ 'ice-cream'
12	/t^{h}ɔj$_2$/ 'table'	31	/lej$_6$/ 'tongue'	50	/tɪn$_6$ si$_6$/ 'television'
13	/k^{h}wɐn$_4$/ 'skirt'	32	/piw$_1$/ 'watch'	51	/kœk$_8$ pan$_2$/ 'sole'
14	/fa$_1$/ 'flower'	33	/k^{h}ɛj$_5$/ 'stand'	52	/sœj$_2$ wu$_2$/ 'kettle'
15	/p^{h}ɪŋ$_4$ kwɔ$_2$/ 'apple'	34	/hɔj$_2$/ 'sea'	53	/faj$_3$ tsi$_2$/ 'chopsticks'
16	/tow$_1$/ 'knife'	35	/ji$_5$/ 'ear'	54	/sɐj$_1$ kwa$_1$/ 'watermelon'
17	/kwa$_1$/ 'melon'	36	/ŋa$_4$/ 'tooth'	55	/sɐj$_6$ min$_6$/ 'wash face'
18	/jy$_2$/ 'fish'	37	/kwɐj$_1$/ 'tortoise'	56	/haw$_6$ fuk$_9$ k^{h}wɐn$_4$/ 'uniform'
19	/ts^{h}ɔŋ$_4$/ 'bed'	38	/p^{h}un$_4$/ 'basin'	57	/naj$_5$/ 'milk'

APPENDIX 2

The phonemic repertoires and phonological processes of three typical children

	Subject 1	Subject 2	Subject 3
Age	2;2	3;2	4;3
Initial consonants	m, n, ŋ, p, t, k, ts, w, j, l	m, n, ŋ, p, t, k, p^h, t^h, k^h, f, s, h, w, j, l	All
Final consonants	All	All	All
Vowels	All	All	All
Tones	All	All	All
Processes	Stopping Fronting Cluster reduction Affrication De-aspiration Final consonant deletion	Stopping Fronting Cluster reduction	None

APPENDIX 3

Order of acquisition of phonemes across languages according to percentage correct scores[a]

% Correct	Cantonese $N = 268$ 2;0–6;0	Japanese $N = 100$ 3;0	Italian $N = 23$ 3;0–4;0	Swedish $N = 32$ 3;0–6;0
99+	p, j, n, ŋ	m, n, t, ŋ, p, j	t, n	
98+	m, w			
97+	t, k		g, d	
94+	h, l	ʧ, ʤ	ʧ, b, l, v	
92+	f, k^h	g, k, b	m	m
90+	p^h, ts	w	ʃ, k, p, s, f	p
89+	s, t^h			
81+	ts^h	d	ʤ, r	b, f, t, h
75+		h	z	n
59+		ʃ		s, v, d, ŋg
40+				j, l, k, R, g
24+		s		ç
9+		z		ɧ

[a] Adapted from Locke (1983: 74–80).