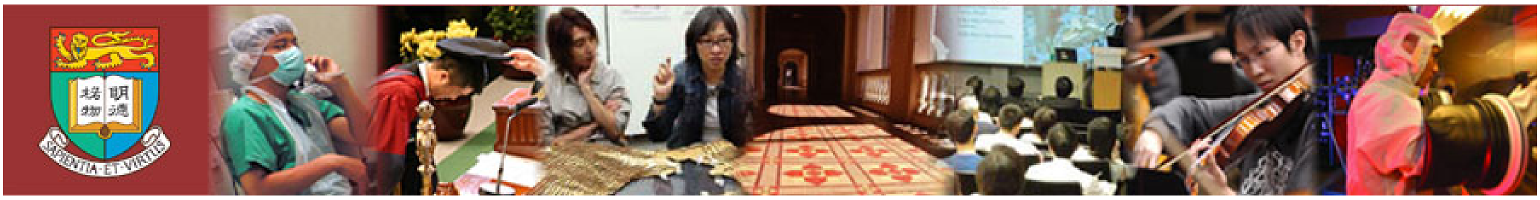

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Other Contributor(s)	University of Hong Kong
Author(s)	Tse, Ka-wing, Karen
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Intelligibility and Acceptability in Cantonese-speaking Children with Cleft Palate: Test Development

Tse Ka Wing, Karen

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Abstract

Many speakers with repaired cleft palate have reduced intelligibility and acceptability, but there are limitations in current procedures as to what aspects of the speakers' speech production are contributing to decreased intelligibility. The aim of this study was to construct a single-word intelligibility test for children with cleft palate, based on a previous test developed for English-speaking children. The test used a word-identification format, based on error patterns found in the speech of children with cleft palate. A phonetic contrast approach was used. Twelve children (eight with cleft palate, four without cleft palate) served as speakers. Twenty listeners were recruited. Intelligibility scores, error patterns, and acceptability ratings were determined. Based on the results of this pilot study, the test has potential to be a clinical tool for the intelligibility assessment of Cantonese-speaking children with cleft palate. Several revisions were recommended for the future development of the test.

Intelligibility and Acceptability in Cantonese-speaking Children with Cleft Palate: Test Development

Cleft palate is a congenital condition affecting between one in 500 and one in 750 live births (Peterson-Falzone, Hardin-Jones, & Karnell, 2001). When clefting has occurred, both the structure and the function of the palate may be compromised (McWilliams, Morris, & Shelton, 1990). Despite surgical repair to the cleft palate, physiological abnormalities such as velopharyngeal incompetence, palatal fistulae, and dental-occlusal abnormalities may affect the speech production in this population (Golding-Kusher, 1995).

Children with cleft palate have been well-documented to be at risk for speech abnormalities such as hypernasality, nasal emission, and articulation errors that involve sustaining intra-oral air pressure (Bzoch, 1997; Peterson-Falzone *et al.*, 2001). Since sufficient intraoral pressure is needed for the production of obstruents, they were reported to be more vulnerable to misarticulations. Most affected sounds are fricatives, plosives and affricates (Albery & Grunwell, 1993; Stengelhofen, 1993), which may be substituted and/ or distorted (Golding-Kusher, 1995). Posterior articulatory placement is common. For example, a backward shift of place from alveolar targets to the palatal, velar or glottal place of articulation has been generally recognized (see McWilliams *et al.*, 1990, for a review). Cluster reduction is found more frequently in children with cleft palate than in normally developing children (Chapman, 1993). Although most children with cleft palate can develop acceptable communication after surgery (Stengelhofen, 1993), an estimated 40% will need to undergo long term speech therapy due to persistent speech defects (Stengelhofen, 1993). Clearly, it is essential to develop structured and systematic procedures for assessing and studying changes of speech behavior for this population (Grunwell, Sell, & Harding, 1993).

Speech intelligibility has been defined as “how well a listener understands [speech]” (Witzel, 1995, p.147). It is a global term of speech performance considered to be a functional indicator of a person’s oral communicative competence (Konst, Weersink-Braks, Rietveld, & Peters, 2000), as well as a guide for treatment effectiveness (Gordon-Brannan & Hodson, 2000). Extensive use and study of intelligibility as a speech measure of interest had been widely reported and recommended (see Whitehill, 2002, for a review). The evaluation of intelligibility can involve both quantitative measurement (degree of intelligibility impairment) and phonological analysis (to determine dimensions of reduced intelligibility) (Kent, Miolo, & Bloedel, 1994). Nevertheless, the clinical assessment components (e.g. speech material, method of assessment and evaluation) of intelligibility vary and there is no consensus available (Kent *et al.*, 1994).

Another global measure, speech acceptability, is also a perceptual construct that has been used to define an individual’s communication competence (Gotzke & Hodge, 2004). It is differentiated from intelligibility and has been defined by Witzel (1995) as “…the subjective impression of the pleasingness of speech” (p.147). Cleft palate speech may not only demonstrate reduced intelligibility, but also a reduction in acceptability that interferes with speech naturalness. Positive correlations between intelligibility and acceptability have been found in the cleft palate population (e.g., Moller & Starr, 1984; Whitehill & Chun, 2002). Although reduction in speech acceptability may imply different treatment approaches from intelligibility intervention (Whitehill, 2002), attempts to investigate acceptability in cleft palate speech have been few (e.g., Lang, Starr, & Moller, 1992; Whitehill & Chun, 2002). It has been reported that articulation and hypernasality are contributors to reduced acceptability in speakers with cleft palate (Whitehill & Chun, 2002). To date, there has been no exploration of the relative correlation between speech acceptability and speech distortion. Speech distortions are prone to reflect dental or occlusal abnormalities and/ or velopharyngeal incompetence in cleft palate speech. Specifically, nasal emission distortions on pressure consonants is a good indicator of velopharyngeal insufficiency and/ or palatal fistulae (Bzoch,

1997) that may affect acceptability. Therefore, a separate investigation on the frequency of occurrence of speech sound distortions may help in identifying the underlying physiological contributions to articulation disorders (Bzoch, 1997).

Transcription, multiple-choice and scaling procedures (such as interval scales) have all been used to evaluate intelligibility (Whitehill, 2002). However, transcription is regarded as “painstaking” (Grunwell *et al.*, 1993, p. 16) and “time consuming” (Konst *et al.*, 2000, p. 485), whereas the validity of interval scales for evaluating intelligibility has been questioned (Kent *et al.*, 1994; Whitehill, 2002). Multiple-choice format has been advocated in recent studies of speech intelligibility for speakers with dysarthria (e.g., Kent, Weismer, Kent, & Rosenbek, 1989; Whitehill and Ciocca, 2000). However, it has been applied less frequently in the cleft palate population (but see Gotzke & Hodge, 2004; Whitehill & Chau, 2004).

The use of single-word identification task has been advocated by Kent *et al.* (1989) for its ease of use as well as its ability to determine segmental contributions to intelligibility. The effect of phonetic contrasts on intelligibility can also be examined by the use of minimal-pair sets in multiple choices (Kent *et al.*, 1989). There have been no systematic investigations of the validity as to whether acceptability is best measured using equal-appearing interval or magnitude estimation scales (but see Southwood, 1990). Nevertheless, interval scaling is the most common method for assessing acceptability in speakers with motor speech disorders (Dagenais, Watts, Turnage, & Kennedy, 1999; Southwood, 1990) as well as speakers with cleft palate (Lang *et al.*, 1992; Moller & Starr, 1984; Whitehill & Chun, 2002).

A single-word intelligibility test for Cantonese speakers with cleft palate using a multiple-choice format has been developed by Whitehill and Chau (2004). Reduced single-word intelligibility in the population (15 Cantonese speakers with repaired cleft lip and palate) was best explained by three phonetic contrasts. They were “place of initial and final stops and nasals”, “stop versus fricative”, and “stop versus affricate”. However, two methodological limitations were identified by the authors. First, as both anterior and posterior place of articulations were incorporated in the phonetic contrasts in the test (for example, plosives at both alveolar and velar place of articulation were targeted in the same contrast), the relative contribution of each of these placement errors to reduced intelligibility could not be determined. Second, the error patterns selected for inclusion in the study were generated from a literature review but not specifically from the subject pool.

The limitations of being “multidirectional” regarding the phonetic contrasts were addressed by Gotzke and Hodge (2004) in which a “unidirectional” minimal-word-pair approach was used in the intelligibility assessment of English-speaking children with cleft palate. The Speech Intelligibility Probe for Children with Cleft Palate, Version Three (SIP_CCLP Ver. 3) (Gotzke & Hodge, 2004) was based on the Test of Children’s Speech (TOCS) for children with motor speech disorders, developed by Hodge (1996). The SIP_CCLP Ver. 3 was based on speech error patterns found in children with cleft palate. The original stimulus words were developed by Connolly (2001) in the Children’s Intelligibility Probe for Cleft Palate. With the use of single word-pairs that vary only in their consonantal constituents, difficulties in a particular manner or place which the child might exhibit were determined (Gotzke & Hodge, 2004). Apart from quantitative measurement of degree of reduced intelligibility in the form of an intelligibility score, the test also measures acceptability impairment as well as distortion rating and proportion of cleft-related errors. In addition, the manner type (e.g. nasals, glides, liquids, stops, fricatives, affricates) that most affects the child’s overall intelligibility is also identified from the phonetic analysis of single word-pairs (Gotzke & Hodge, 2004). Specific analysis of error patterns allows identification of particular sounds that contribute to reduced intelligibility. As presence of cleft errors may mask phonological immaturities unrelated to the cleft (Harding & Grunwell, 1996), inclusion of developmental errors in addition to cleft-related errors was advocated by Gotzke and Hodge (2004).

The current test was carried out by adapting the approaches employed by Gotzke and Hodge (2004), for a Cantonese population. Specific directions of phonetic contrasts were incorporated into minimal-pair contrasts. Error types were categorized as per Gotzke and Hodge (2004), and both developmental and cleft-related errors were included. Phonetic feature analyses of the errors in terms of manner and place of articulations were provided. Phonetic contrast profiles for speakers in both cleft and noncleft groups were generated.

The primary aim of this study was to pilot a quantitative and analytic single-word intelligibility test for Cantonese-speaking children with cleft palate, based on minimal-pair phonetic contrasts. Evaluation of acceptability and a measure of distortion were also included. In order to examine the sensitiveness of the phonetic contrasts to the cleft palate population, children with and without cleft palate were included. It was predicted that children with cleft palate would demonstrate more cleft-related errors than children without cleft palate. Specifically, the following questions were posed: (1) what is the correlation between speech intelligibility and acceptability in this population? (2) What is the correlation between the perceptual judgment of acceptability and distortion ratings? (3) What is the difference between children with and without cleft palate in terms of overall intelligibility scores and error patterns? By comparing and analyzing the differences of overall intelligibility score and error patterns between these two groups, it is believed that a reliable and valid pilot test can be constructed to assess the speech intelligibility and acceptability of Cantonese-speaking children with cleft palate.

Method

Participants

The subjects were eight Cantonese-speaking children with repaired cleft palate (with or without cleft lip) and four noncleft Cantonese-speaking children with typical speech and language development. Age of primary palatal repair was between 12-18 months. The cleft group had a mean age of 7;06 years (range: 4;10-10;00) and the noncleft group had a mean age of 3;01 years (range: 2;03- 3;09). Since Cantonese-speaking children develops early phonologically and few errors would be made after the age of 4;00 (So & Dodd, 1995), the noncleft group had to be below 4;00 so that they would demonstrate some developmental errors. Therefore, age-matching was not possible in this pilot study. Appendix A presents additional subject information.

Speakers with cleft palate were recruited from the Cleft Lip and Palate Centre, Prince Philip Dental Hospital, the University of Hong Kong. All cleft speakers had no history of cleft-related syndrome, neurologic impairment, or intellectual deficits. The noncleft speakers were recruited through personal contacts. These noncleft speakers had no history of speech or language problems or intellectual deficits. None of the children exhibited hearing impairment according to clinical or parental reports. All subjects in both groups were native-Cantonese speakers.

The listeners were 36 native-Cantonese speakers with normal hearing. They were undergraduate final-year students studying speech and hearing sciences at the University of Hong Kong. They had no expertise in evaluating cleft palate speech. The use of non-expert listeners reflected the realities of clinical practice in Hong Kong, where most clinicians treating speakers with cleft palate are not specialist in orofacial or resonance disorders (Chun & Whitehill, 2001).

Materials

A single-word intelligibility test using a single word-pair format was constructed. This test was based on the SIP_CCLP Ver. 3 (Gotzke & Hodge, 2004). Both closed-set (i.e. phonetic contrast identification) and open-set (i.e. word identification) response tasks were employed in the SIP_CCLP Ver. 3 (Gotzke & Hodge, 2004). A phonetic contrast approach was used for the close-set response task. Each target word in the test differed from the foil by one phonetic feature. For example, for the target word /$\underline{f}an_{22}$/ (飯), the foil would be /$\underline{m}an_{22}$/ (慢) in which only the consonantal contrast (fricative versus nasal contrast) was targeted. After listening to a single-word, listeners were instructed to select the word that was heard. Listeners were then instructed to rate the selected word as "clear" or "distorted" to indicate if there was any speech sound distortions. In the open-set response task, listeners were instructed to do orthographic transcriptions of single-words. For both closed-set and open-set response task, intelligibility was defined as the percentage of words correctly identified. Acceptability was evaluated upon completion of the entire close-set as well as open-set response task for an individual speaker, using a seven-point equal-appearing interval rating scale.

In this study, consonants in the syllable initial as well as final positions were targeted (Gotzke & Hodge, 2004). Grouping of phonetic contrasts followed closely that of SIP_CCLP Ver. 3 (Gotzke & Hodge, 2004) but was revised to be more sensitive to Cantonese phonology. For example, voicing errors in the English version of the test were replaced with aspiration errors because Cantonese does not have a voicing distinction but contrastive aspiration (So & Dodd, 1995). Additional contrasts such as "fricative versus nasal" (/f/ → [m]) was included in the test as this contrast was also frequently reported in speakers with cleft palate (see Whitehill & Chau, 2004). Word-pairs were phonologically categorized into manner preference, place preference, manner and place preference, aspiration error, syllable structure and sibilant distortion. All of these were classified under cleft-related errors, developmental errors and “unexpected” errors (errors which had insufficient information to be categorized as neither cleft-related nor developmental). Grouping details are shown in Appendix B. The minimal pair contrasts were determined by Gotzke and Hodge (2004) based on literature review that identified errors problematic for speakers with cleft palate. Developmental errors were determined based on Cheung and Abberton (2000) and So and Dodd (1995). Phonetic contrasts involving vowels and tones were not included in the test because they are known to be robust in Cantonese (Cheung & Abberton, 2000; So & Dodd, 1995).

As in other intelligibility tests in Cantonese (e.g., Whitehill & Chau, 2004; Whitehill & Ciocca, 2000), contrasts between Cantonese free variations (e.g. initial /n/ → /l/ and initial /ŋ/ ↔ /ɸ/) were not included in the test. The Cantonese segments /kw/ and /kʰw/ were considered as clusters in this study (So & Dodd, 1995). After these modifications, a total of 136 targets were used for the analysis of intelligibility. Appendix B contains a list of all stimulus words used in this test, as well as the error pattern categorization (“grouping”).

Procedures

The procedures were modelled after Connolly (2001) and Gotzke and Hodge (2004).

Speech data collection. As some of the targets words in the test were used for more than one contrast in the listening task, only 101 targets were recorded from the speakers. The 101 targeted Chinese characters and their phonetic transcriptions were written on white cards to ensure consistent pronunciation by the examiner since some Chinese words have more than one pronunciation. The order of presentation of the stimuli was randomized by shuffling all 101 stimulus cards before each recording. Speakers were instructed to repeat the stimuli after the examiner. Four practice items preceded the presentation of actual stimulus words to ensure the speakers understood the task. Rate of presentation was controlled at about three seconds per word. Administration of the recording procedure lasted for about 25 minutes.

Speech data were collected individually in a quiet room using a Sony MZ-R900 minidisk player and a Shure BG 1.1 low noise, unidirectional microphone. Mouth-to-microphone distance was kept constant at 10 cm.

Listening task. The speech samples were low-pass filtered at 22 kHz and converted into digital files at a sampling rate of 44.1 kHz using an IBM ThinkPad X21 computer with WavePad Version 1.11. Each word was saved as a separate file. All listening tasks were administered individually in a sound booth. The samples were presented through an IBM ThinkPad X21 computer using Audio-Technica ATH-T2 headphones. The playback volume was set to a comfortable level before the listening task began. Listener judgments were obtained using paper and pencil tasks.

A sample response form is shown in Appendix C. The response forms were presented in a multiple-choice format. Each Chinese character in the response form was also phonetically transcribed. Listeners heard a single word and were instructed to focus on the phoneme in the underlined position in the first column (phonetic contrast). They were instructed to choose between the target word and the target word’s phonetic contrast by circling one option. If the listener was not comfortable selecting one of the two options, the second column allowed the listener judges to indicate the phoneme heard by providing a phonetic transcription. They were allowed to choose the final column (“?”) if they could not identify the phoneme that was heard at all. The listener judges were instructed to rate each production as “clear” or “distorted”, if one of the first three options was selected (either member of the phonetic contrast pair or a provided transcription). Four practice items were given prior to the actual listening task. During the actual task, listener judges were allowed to repeat each stimulus once. After completion of the task for one speaker, they were instructed to rate the acceptability of the child’s speech using a seven-point equal-appearing interval rating scale (1 = highly unacceptable and 7 = highly acceptable). A written definition of acceptability was provided based on Witzel (1995). There was no time limit for listeners to make a judgment.

The presentation of stimuli in the listening task followed the order of occurrence in the shuffling procedure during data collection. Each speaker was judged by three listener judges. Each listener judge was required to listen to three speakers. Listening order was balanced by block randomization of speakers. Fourteen stimulus words were randomly selected from the 136 targets for intralistener reliability. A total of 150 response judgments were required to be made for each speaker. Each listening task for all three speakers lasted for about one hour.

Data Analysis

Reliability

The mean percentage of intelligibility agreements ± 3% and ± 5% across each listener (in each group of three listeners) was determined for interlistener reliability. Listener's agreements for the 14 repeated items were converted to a mean percentage of agreements across listeners to determine intralistener reliability. Interlistener agreements for acceptability were determined by mean percentage of exact agreement and within one scale value agreement across listeners.

Intelligibility Analysis

Individual intelligibility scores were determined by dividing the total number of items for which a minimum of two out of three listeners chose the target response by the total number of targets, and converting to a percentage. Standard deviations of intelligibility were determined.

Speech Acceptability and Distortion Analysis

The median ratings for the three listener judges for each speaker were used as the acceptability score for each speaker. Semi-interquartile range (Q) of acceptability was determined. Distortion ratings were determined by calculating the number of items for which two out of three listeners judged as “distorted”. The total number of distorted items out of the total number of items was converted to percentages.

Correlations between Measures

The correlations between intelligibility and acceptability, and between acceptability and distortions were examined using Spearman Rank-order Correlation Coefficient.

Phonetic Analysis

Items for which two out of three listeners chose or wrote down the same response were determined as the error pattern (or correct response) for each speaker. The mean percentage of cleft-related errors was calculated by percentage of cleft-related errors out of total number of errors. Errors were further broken down into categories (i.e. manner errors, place errors etc). Percentages of errors in each category were analyzed out of total number of errors. Errors were also analyzed by manner and place of articulations for both groups (cleft and noncleft). Between-group comparisons were examined using Mann-Whitney *U* test. Finally, the patterns of cleft-related and developmental errors that emerged from this study were analyzed in detail for both cleft and noncleft group.

Results

Reliability

Interlistener intelligibility agreement (± 3%) was 77.78% (range: 0%-100%). The ± 5% agreement score was 86.11% (range: 33%-100%). Mean intralistener intelligibility agreement was 96.63% (range: 85.71%-100%). Mean exact agreement among the listeners for speech acceptability was 50% (range: 0%-66.7%); one scale agreement was 77.78% (range: 66.67%-100%).

Intelligibility

Intelligibility ranged from 65.19% to 97.06%, with an overall mean score of 79.76% for the cleft group. For the noncleft group, intelligibility ranged from 57.04% to 87.41% with a mean of 68.78%. Individual and group intelligibility scores are summarized in Table 1.

Speech Acceptability

As shown in Table 1, median acceptability ranged from 3-6 with a mean score of 4.88 for the cleft group. For the non-cleft group, median acceptability ranged from 3-5 with a mean of 3.75.

Table 1

Intelligibility (I), Acceptability (A), Distortion (D), and Cleft Related Errors (CRE) Scores for Individual Speakers and Groups

Cleft Palate Group					Noncleft Palate Group				
Subject	I (%)	A	D (%)	CRE (%)	Subject	I (%)	A	D (%)	CRE (%)
C1	88.89	5	32.35	26.67	NC1	61.76	4	11.03	1.92
C2	77.21	5	15.44	87.10	NC2	68.89	3	11.03	4.76
C3	65.19	5	3.68	91.49	NC3	87.41	5	2.21	29.41
C4	71.11	3	40.44	23.08	NC4	57.04	3	36.76	3.45
C5	97.06	5	3.68	50					
C6	75.94	5	27.94	9.38					
C7	76.68	5	25.74	40					
C8	86.03	6	11.76	78.95					
M	79.76	4.88	20.13	50.83	M	68.78	3.75	15.26	9.89
SD	10.28	-	13.56	31.05	SD	13.34	-	14.93	13.07
Q	-	0	-	-	Q	-	1	-	-

Correlations between Measures

There was a moderately strong correlation between intelligibility and acceptability (Spearman's $R = 0.65$, $p < 0.05$). The correlation between acceptability and distortion was not significant (Spearman's $R = -0.33$, $p = 0.29$).

Phonetic Analysis

Cleft-related errors. The number of cleft-related errors (CRE) was significantly larger in the cleft group than noncleft group (Mann-Whitney $U = 3.00$, $p < 0.05$) (Table 1). As expected, the frequency of substitution errors characterized as cleft-related was low for the noncleft subjects, only 9.89% of the total numbers of errors. One subject in the noncleft group (NC3) produced a high number of backing process in the production of alveolar stops (/t/ → [k]) and contributed to a high percentage of cleft-related errors. For the cleft group, a mean of 50.83% of the errors were solely cleft-related. A subject in the cleft group (C6) produced a high number of affrication and deaffrication processes and resulted in a low percentage of cleft-related errors.

Error types. As seen in Table 2, error types were further broken down into seven groups according to the features disrupted: manner, place, manner + place, aspiration, syllable structure, sibilant distortion, and "other". The last category was termed "other" because it did not correspond to any of the categories targeted in the test design. An example would be a realization with both manner and aspiration errors. Only one subject in the noncleft group (NC4) produced such errors. Although the difference in percentage of place errors was not significant between the two groups, there was a tendency towards a higher percentage of place errors in the cleft group than in the noncleft group ($u = 12$, $p = 0.50$). There was also tendency towards higher percentage of manner errors produced by the noncleft group ($u = 12$, $p = 0.50$). Aspiration errors were not produced by any of the subjects in the cleft group, but were demonstrated by all children in the noncleft group ($u = 4$, $p < 0.05$). No statistical

Table 2

Mean Error Types Expressed as Percentage

	Manner	Place	Manner+Place	Aspiration	Syllable Structure	Sibilant Distortion	Others
Cleft	39.85	26.95	14.70	0.00*	16.26	2.23	0
Noncleft	45.66	18.04	6.92	21.45*	2.43	1.62	13.79

*$p < 0.05$, Mann-Whitney *U* test.

difference was evident between the two groups in terms of percentage of errors involving syllable structure ($u = 8$, $p = 0.17$), although the cleft group had more than 13 percentage more errors than the non cleft group (16.26% versus 2.43%).

Manner/ Place Analysis of Correct Targets. Correct target sounds were analyzed by manner and place of articulation for the two groups (Table 3). The “null” category in Table 3 refers to items that targeted initial /ɸ/. For this analysis, clusters /kw/ and /k^hw/ were considered stops in terms of manner of articulation and velars in terms of place of articulation. Regarding manner of articulation, children in the cleft group produced all nasals and liquids correctly; fricatives and affricates were particularly vulnerable to errors (both were < 70% correct). There was a statistically higher accuracy for sonorants over obstruents in the cleft group ($u = 3$, $p < 0.005$), which was typical in the cleft palate population. Statistically higher accuracy for sonorants over obstruents was also shown in the noncleft group ($u = 1$, $p < 0.05$). However, an inspection of the phonetic contrasts in the noncleft group (Table 4) indicated the obstruents errors were mostly due to deaspiration, deaffrication, or stopping of the plosives or affricates, which were developmental.

Regarding place of articulation, the cleft group produced a higher percentage of correct targets at the posterior place of articulation (i.e. palatal, velar and glottal, 93.18%) than the anterior place (i.e. bilabial, labiodental, alveolar and labiovelar, 83.59%). However, this difference was not statistically significant ($u = 3$, $p = 0.29$). For the noncleft group, alveolar and velar places of articulation were the least accurate (with correct production of 59.56% and 48.86% respectively). Closer examination (Table 4) revealed that developmental errors such as deaffrication and stopping of alveolar fricatives and affricates as the main contributors to the errors exhibited at the anterior places of articulation. There was no statistical difference between the two groups for any manner or place of articulation ($p > 0.05$).

Phonetic contrast analysis. Table 4 shows the frequency of occurrence of specific cleft-related and developmental phonetic contrasts errors for individual speakers in the two groups. For the purpose of this analysis, “unexpected errors” were not included. Error patterns exhibited in the cleft group was not uniform; there was large individual variability across

Table 3

Mean Percentage of Correct Targets Organized by Manner and Place of Articulation

Manner			Place		
	Cleft	Noncleft		Cleft	Noncleft
Stops	81.56	65.16	Bilabial	89.94	84.38
Fricatives	69.14	89.06	Labiodental	80	95
Affricates	69.08	18.42	Alveolar	72.24	59.56
Nasals	100	91.67	Palatal	100	100
Liquids	100	79.17	Velar	79.55	48.86
Glides	93.06	97.22	Glottal	100	100
Null	97.92	95.83	Labiovelar	92.19	96.88
			Null	97.92	95.83

Table 4

Distribution of Phonetic Contrast Errors by Individual Subject

	Cleft Palate Group								Noncleft Palate Group			
	Subject								Subject			
Cleft-Related	C1	C2	C3	C4	C5	C6	C7	C8	NC1	NC2	NC3	NC4
Errors (Total)	(15)	(31)	(47)	(39)	(4)	(32)	(35)	(19)	(52)	(42)	(17)	(58)
alveo-labioden fric	1	-	-	1	-	-	-	-	-	-	-	1
stop-null	-	1	-	-	-	-	-	5	-	-	1	-
affric-null	-	-	-	-	-	-	-	-	-	-	-	-
stop-glottal fric	-	-	-	-	-	-	-	-	-	-	-	-
alveo-velar stop, I/F	2	-	14	1	1	1	1	-	1	2	4	1
alveo-bilab stop, I/F	-	3	3	2	1	-	-	-	-	-	-	-
stop-sonorant	-	7	-	1	-	-	-	2	-	-	-	-
fric-sonorant	-	-	5	-	-	-	-	-	-	-	-	-
affric-sonorant	-	9	3	-	-	-	-	-	-	-	-	-
oral stop-nasal, I/F	-	6	-	4	-	-	-	7	-	-	-	-
fric-nasal	-	-	-	-	-	-	-	-	-	-	-	-
affric-fric	-	-	-	-	-	-	-	-	-	-	-	-
affric-velar stop	1	-	-	-	-	-	8	-	-	-	-	-
affric-nasal	-	1	-	-	-	-	-	-	-	-	-	-
fric-glottal fric	-	-	18	-	-	2	-	-	-	-	-	-
fric-velar stop	-	-	-	-	-	-	5	-	-	-	-	-

(continued)

(Table 4, continued)

	Cleft Palate Group								Noncleft Palate Group			
	Subject								Subject			
Developmental	1	2	3	4	5	6	7	8	1	2	3	4
Errors (Total)	(15)	(31)	(47)	(39)	(4)	(32)	(35)	(19)	(52)	(42)	(17)	(58)
Deaspiration (stop)	-	-	-	-	-	-	-	-	26	1	-	18
Deaspiration (affric)	-	-	-	-	-	-	-	-	-	-	-	-
Fronting	3	-	2	4	-	2	2	-	4	8	2	1
Stopping	4	-	1	20	-	1	2	-	7	19	-	16
Affrication	-	-	-	-	1	16	8	-	-	-	3	-
Deaffrication	-	-	-	1	-	10	-	-	12	-	7	1
Cluster Reduction	2	2	-	3	-	-	-	3	-	-	-	-
cluster-velar stop	2	-	-	-	-	-	-	1	-	-	-	-
cluster-bilab stop	-	-	-	-	-	-	-	-	-	6	-	-
Others	-	-	-	-	-	-	-	-	-	-	-	9

Notes.

1. Numbers in parentheses represents total number of errors for each speaker.
2. Alveo = alveolar; labioden = labiodental; fric = fricative; affric = affricate; bilab = bilab; I = initial position; F = final position
3. Contrasts in italics indicate contrasts that were not included in the initial design of this test, but were demonstrated by the subjects as indicated by listeners' phonetic transcriptions.

both cleft-related and developmental error types. Additional error patterns, not included in the original test contrasts but subsequently identified as cleft-related, were identified in the cleft group. They were affricate versus velar stop, affricate versus nasal, fricative versus glottal fricative, and fricative versus velar stop. A total of 18 phonetic contrasts were exhibited by the cleft group. The noncleft group was more homogenous; only 10 phonetic contrasts were identified, among which seven of them were developmental. The final category of “other” was added because a few of the processes co-occurred (e.g. stopping plus deaspiration); these were demonstrated by one subject (NC4) only.

Among the cleft-related phonetic contrasts (Table 4), almost all subjects (except for CP2 and CP8) demonstrated problems with a single contrast: alveolar versus velar stop (initial and final). The five most problematic phonetic contrasts in the cleft group were, from most to least severe, alveolar versus velar stop (initial and final), fricative versus glottal fricative, oral stop versus nasal (initial and final), affricate versus sonorant, and stop versus sonorant. These contrasts together accounted for 68.10% of the total number of cleft-related errors for the speakers in the cleft group. All subjects in the noncleft group produced fronting. In descending order of frequency, deaspiration of stops, stopping, deaffrication as well as fronting were the four most prominent processes in the noncleft group. These substitution patterns together accounted for 87.14% of the total number of developmental errors in the noncleft group.

Discussion

The primary aim of this study was to develop a quantitative and analytic single-word intelligibility test for Cantonese-speaking children with cleft palate. A single-word intelligibility test for Cantonese speakers with cleft palate has been developed by Whitehill and Chau (2004), but the directions of problematic phonetic contrasts were not determined from the test. As a pilot study with a relatively small sample size, the results obtained might need to be interpreted with caution. Using a phonetic contrast approach, the test was developed to be sensitive to the error patterns of children with cleft palate. Both cleft-related and developmental errors were identified and in-depth analysis in terms of manner and place of articulations were obtained. With specific analysis of error patterns, potential sources of unintelligibility were discovered. By measuring both speech intelligibility and acceptability systematically, the severity of the speech impairment of children with cleft palate was determined (Kent *et al.*, 1989).

The mean intelligibility score for the cleft group was 79.76% and the noncleft 68.78%. The mean for the cleft group was influenced by one subject who had an intelligibility score of 97.06%. Young children aged below 4;00 were deliberately chosen to be included in the noncleft group as they might be showing some developing errors (So & Dodd, 1995). The moderately strong correlation between intelligibility and acceptability ($R = 0.67$, $p < 0.05$) indicated that the two measures are closely related aspects of speech, albeit not identical (Whitehill & Chun, 2002). Individual investigation of the data revealed that there were speakers (e.g. CP5) in which a high intelligibility score was occurred with a relatively low acceptability rating. A differentiation between speech intelligibility and acceptability may render different intervention approaches and prioritizations (Whitehill, 2002). Although no significant correlation between acceptability and distortion was noted in this study, rating of distortions is an important clinical procedure to capture any distorted articulations that is frequently present in cleft palate speech (Bzoch, 1997). For example, nasal emissions may bring articulatory distortions but may have no or little degrading effects on intelligibility, unless they are so severe as to lead to loss of pressure consonants (Peterson-Falzone *et al.*, 2001). Although it was not possible to determine the potential sources of distortion ratings in the test, possible contributors could be that of nasal air emission, palatalization, and/ or weak pressure consonants, which is the most frequent and salient feature of cleft palate speech (Trost-Cardamone, 1990).

A tendency was observed in which the cleft group were prone to make less errors in manner of articulation and more in place of articulation than the noncleft group. Specifically, the two most vulnerable phonetic contrasts obtained in the cleft group involved a the change of place of articulation, where the manner features of stop and fricative were preserved, with a backward shift to velar and glottal place respectively. Shifting of place with maintenance of manner has been widely reported (e.g., Stengelhofen, 1993), and explained by an attempt to produce what most resembles the target sound so as to minimize intelligibility loss. The high incidence of errors in syllable structure in the cleft group pertained to initial consonant deletion and cluster reduction. Similar results were obtained by Stokes and Whitehill (1996) in their study of Cantonese-speaking children with cleft palate. Consonant deletion was explained by Kummer (2001) as a result of air pressure leakage through the velopharyngeal valve; consequently, consonants may sound weak in intensity and pressure which were perceived as omissions by listeners. Although cluster reduction (/kw/ → [w]) was considered as a developmental process in Cantonese phonology, it was suggested that reduction of velar plosives in the clusters was due to air pressure leakage, leaving the glides intact. Final consonant deletions were relatively spared in both of the groups; similar observations were obtained by Stokes and Whitehill (1996).

There was a statistically higher accuracy for sonorants over obstruents in the cleft group; the pattern was evidenced by the other three most vulnerable contrasts: oral stops were produced in place of their nasal counterparts, and stops and affricates were substituted by sonorants. These were considered to be related to a loss of sustained intraoral pressure needed in the production of obstruents consonants (Albery & Grunwell, 1993). Nasal release of the intraoral pressure required in production of oral stops may lead to approximations to their nasal cognates. Moreover, while sonorants place less demand on tight closure of velopharyngeal mechanism than obstruents, sonorants are then precipitated when air pressure cannot be sustained inside oral cavity during obstruents production (Gotzke & Hodge, 2004).

Phonemes targeted at the anterior place of articulation were more susceptible to error than those that were produced posteriorly in the cleft group. According to previous studies, these errors appear to occur as a consequence of physiological limitations (such as poor velopharyngeal closure, dental malocclusion), as well as subconscious habitual learning within the cleft palate individual in order to maximize the range of meaningful contrasts (Harding & Grunwell, 1996). Stopping (/s, ts/ → [t]) occurred to be the most prevalent process among the cleft palate children, which could be explained as an avoidance of faulty articulation of fricatives (Harding & Grunwell, 1996). Similarly, it was suggested that stopping of affricates /ts and ts^h/ in the cleft group were to be explained by the avoidance behavior as well. As such, although these processes were classified as developmental errors, their underlying causes could also be cleft-related for speakers in the cleft group (Harding & Grunwell, 1996).

The phonological processes noted in the noncleft group were consistent with the phonological development in Cantonese-speaking children, as reported by Cheung and Abberton (2000) and So and Dodd (1995). Backing of an alveolar stop to a velar stop was also noted infrequently in the noncleft group. The backing process is described as a common process in disordered speech in Cantonese, but it also appears very infrequently in normal Cantonese acquisition (Cheung & Abberton, 2000).

Recommended Future Developments

Based on the results obtained in this pilot study, several refinements for future test development were suggested. Recommended revisions include: revising the type of target phonetic contrasts, computer-administration of the test, provision of a definition of distortion, and evaluation of validity and reliability of the test as a measure of speech intelligibility.

Regarding target contrast revision, three additional phonetic contrasts are proposed to be added as cleft-related errors. These are: fricative versus glottal fricative, fricative versus velar stop, and affricate versus velar stop. The contrasts were not included in SIP_CCLP Ver. 3. Specifically, “fricative versus glottal fricative” appears to be a language-specific error for Cantonese-speaking children with cleft palate (Stokes & Whitehill, 1996). There are three fricatives in Cantonese phonology: the labiodental /f/, the alveolar /s/, and the glottal /h/. The manner of frication is maintained to a high degree in Cantonese-speaking children with cleft palate (Stokes & Whitehill, 1996). Therefore, when the labiodental or alveolar targets could not be achieved, a glottal realization was preferred. Besides, to better reflect developmental errors in Cantonese, it was recommended that cluster reductions in terms of delabializing to [k], delabializing and fronting to [t], [p] and [f] be included under this process. These processes were also commonly found in normal Cantonese acquisition (Cheung & Abberton, 2000). For these reasons, the phonetic contrasts in cleft-related as well as developmental errors were to be revised to cater for the specificity of the Cantonese-speaking population.

Following the procedures for the SIP_CCLP Ver. 3 administration, future development of this Cantonese version should include computer-administration of speech recordings as well as listening tasks. To enhance the cooperation and interest of young children during the recording procedures, the repetition task could be accompanied by computerized photos or clip art during data collection. In this way more accurate data can be obtained with higher efficiency. Instead of a paper and pencil task, the listening task could be carried out by a computer program in which stimuli could be automatically randomized; listeners’ responses could also be collected and analyzed by the computer software.

A concern expressed by some listeners was that it might have been difficult to standardize listeners' understandings of what should be regarded as "clear" versus "distorted" during rating of distortion in the test. Similar to speech acceptability, a definition of distortions was suggested to be provided in the future test so as to provide listeners with a common definition of distortion. The provisional definition would be "a phonemic sound element of a syllable judged to be somewhat distorted by imprecise articulation production, but nevertheless a close approximation of the sound attempted", as suggested by Bzoch (1997, p. 292).

One final recommendation for future development would be extension of the evaluation of validity (content, construct, criterion) and reliability (interjudge, intrajudge) with a larger sample of children, including age-matched children with and without cleft palate. Although this study revealed the kind of errors made by children with cleft palate, and was sensitive to the developmental errors, systematic group comparisons in terms of mean intelligibility scores, developmental and cleft-type error patterns were not viable in this pilot study due to the small sample size.

Conclusion

The purpose of the current study was to construct a Cantonese version of the SIP_CCLP Ver. 3 (Gozke & Hodge, 2004). Target words and foils were chosen and incorporated into minimal-pair phonetic contrasts. Phonetic contrasts were modified to be sensitive to the articulatory problems experienced by Cantonese-speaking children with cleft palate. Apart from speech intelligibility, acceptability and distortion measures were also included in the test so that dimensions not directly related to impaired intelligibility could also be examined. The study and test provided detailed assessment as to whether the speech errors in the cleft group were predominantly cleft-related or developmental, or, a combination of both. The results indicated that this test included an extensive list of phonetic contrasts that were sensitive to the cleft palate population. The procedures allowed unbiased intelligibility ratings as well as identification of phonetic errors that contributed to reduced intelligibility in the cleft palate population.

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Appendix A

Subject Details

Subject group	Subject number	Age	Gender	Type of cleft palate
Cleft Palate	CP1	10;00	M	Unilateral cleft lip and palate
Cleft Palate	CP2	9;10	F	Unilateral cleft lip and palate
Cleft Palate	CP3	4;10	F	Cleft palate only
Cleft Palate	CP4	8;04	F	Unilateral cleft lip and palate
Cleft Palate	CP5	8;04	M	Unilateral cleft lip and palate
Cleft Palate	CP6	6;06	F	Cleft palate only
Cleft Palate	CP7	6;05	M	Cleft palate only
Cleft Palate	CP8	8;00	M	Unilateral cleft lip and palate
Noncleft Palate	NC1	3;03	M	n/a
Noncleft Palate	NC2	2;03	M	n/a
Noncleft Palate	NC3	3;09	M	n/a
Noncleft Palate	NC4	3;02	F	n/a

Appendix B

Phonetic Contrast Table

Error type	Error pattern	Contrast	Item no. (total)	Item no. (each pattern)	Token	Phonetic transcription (IPA)	English translation	
							Target	Foil
I. Cleft-related Errors	**A. Sibilant Distortion**	**alveolar fricative→ labiodental fricative**	1.	1.	山 → 翻	/san$_{55}$/ - /fan$_{55}$/	hill	turn
			2.	2.	細 → 肺	/sɐi$_{33}$/ - /fɐi$_{33}$/	small	lung
			3.	3.	手 → 否	/sɐu$_{35}$/ - /fɐu$_{35}$/	hand	not
			4.	4.	玩鎖 → 玩火	/wan$_{21}$ sɔ$_{35}$/ - /wan$_{21}$ fɔ$_{35}$/	play lock	play with fire
			5.	5.	買沙 → 買花	/mai$_{23}$ sa$_{55}$/ - /mai$_{23}$ fa$_{55}$/	buy sand	buy flower
	B. Syllable Structure	**stop → null**	6.	1.	爸 → 鴉	/pa$_{55}$/ - /a$_{55}$/	father	crow
			7.	2.	多 → 痾	/tɔ$_{55}$/ - /ɔ$_{55}$/	many	toileting
			8.	3.	呔 → 唉	/t^{h}ai$_{55}$/ - /ai$_{55}$/	tie	oh
			9.	4.	靠 → 坳	/k^{h}au$_{33}$/ - /au$_{33}$/	rely	pass
			10.	5.	想爸 → 想鴉	/sœŋ$_{35}$ pa$_{5}$/ - /sœŋ$_{35}$ a$_{55}$/	miss daddy	'think crow'
			11.	6.	葉 → 易	/jip$_{2}$/ - /ji$_{22}$/	leaf	easy
			12.	7.	八 → 霸	/pat$_{3}$/ - /pa$_{33}$/	eight	tyrant
			13.	8.	角 → 個	/kɔk$_{3}$/ - /kɔ$_{3}$/	bed	(particle)
		affricate → null	14.	1.	讚 → 晏	/tsan$_{33}$/ - /an$_{33}$/	praise	late
			15.	2.	滿載 → 滿愛	/mun$_{33}$ tsɔi$_{33}$/ - /mun$_{33}$ ɔi$_{33}$/	fully carry	full of love
			16.	3.	測 → 握	/ts^{h}ak$_{5}$/ - /ak$_{5}$/	test	hold
	C. Place Preference	**alveolar stop → velar stop, I/F**	17.	1.	豆 → 狗	/tɐu$_{35}$/ - /kɐu$_{35}$/	bean	dog
			18.	2.	停 → 鯨	/t^{h}ɪŋ$_{21}$/ - /k^{h}ɪŋ$_{21}$/	stop	whale
			19.	3.	三打 → 三家	/sam$_{55}$ ta$_{55}$/ - /sam$_{55}$ ka$_{55}$/	three dozen	three families
			20.	4.	膝 → 塞	/sɐt$_{5}$/ - /sɐk$_{5}$/	knee	block/ cork

	alveolar stop → bilabial stop, I/F	21.	1.	停 → 平	/t^{h}ɪŋ$_{21}$/ - /p^{h}ɪŋ$_{21}$/	stop	level/ even
		22.	2.	多 → 波	/tɔ$_{55}$/ - /pɔ$_{55}$/	many	ball
		23.	3.	擦膠 → 插膠	/ts^{h}at$_{33}$ kau$_{55}$/ - /ts^{h}ap$_{33}$ kau$_{55}$/	eraser	‘insert plastic’
		24.	4.	咳 → 給	/k^{h}ɐt$_{5}$/ - /k^{h}ɐp$_{5}$/	cough	give
		25.	5.	舌 → 攝	/sit$_{2}$/ - /sip$_{2}$/	tongue	capture
D. Manner Preference	**stop → sonorant**	26.	1.	停 → 零	/t^{h}ɪŋ$_{21}$/ - /lɪŋ$_{21}$/	stop	zero
	fricative → sonorant	27.	1.	手 → 褸	/sɐu$_{35}$/ - /lɐu$_{35}$/	hand	coat
		28.	2.	無星 → 無拎	/mou$_{21}$ sɪŋ$_{55}$/ - /mou$_{21}$ lɪŋ$_{55}$/	no star	‘no carry’
	affricate → sonorant	29.	1.	床 → 狼	/ts^{h}ɔŋ$_{21}$/ - /lɔŋ$_{21}$/	bed	wolf
		30.	2.	走 → 樓	/tsɐu$_{35}$/ - /lɐu$_{35}$/	run	flat
	oral stop → nasal, I/F	31.	1.	飽 → 貓	/pau$_{55}$/ - /mau$_{55}$/	bread	cat
		32.	2.	豆 → 鈕	/tɐu$_{22}$/ - /nɐu$_{22}$/	bean	button
		33.	3.	小道 → 小怒	/siu$_{35}$ tou$_{22}$/ - /siu$_{35}$ nou$_{22}$/	small road	‘little anger’
		34.	4.	立 → 艦	/lap$_{22}$/ - /lam$_{22}$/	stand	warship
		35.	5.	一 → 欣	/jɐt$_{5}$/ - /jɐn$_{55}$/	one	happiness
		36.	6.	滴 → 定	/tɪk$_{22}$/ - /tɪŋ$_{2}$/	drop	set/ sure
	fricative → nasal	37.	1.	手 → 鈕	/sɐu$_{35}$/ - /nɐu$_{35}$/	hand	button
		38.	2.	水 → 女	/sɸi$_{35}$/ - /nɸi$_{35}$/	water	female
E. Manner & Place Preference	**stop → glottal fricative**	39.	1.	跑 → 考	/p^{h}au$_{35}$/ - /hau$_{35}$/	run	test
		40.	2.	頭 →	/t^{h}ɐu$_{21}$/ - /hɐu$_{21}$/	head	monkey
		41.	3.	琴 → 含	/k^{h}ɐm$_{21}$/ - /hɐm$_{21}$/	piano	keep in mouth
		42.	4.	小窮 → 小熊	/siu$_{35}$ k^{h}uŋ$_{21}$/ - /siu$_{35}$ huŋ$_{21}$/	very poor	little bear

stop → sonorant	43.	1.	破 → 喎	/pʰɔ$_{33}$/ - /wɔ$_{33}$/	broken	(particle)
	44.	2.	波 → 鍋	/pɔ$_{55}$/ - /wɔ$_{55}$/	ball	pot
	45.	3.	聽 → 鷹	/tʰɪŋ$_{55}$/ - /jɪŋ$_{55}$/	listen	eagle
	46.	4.	丁 → 鷹	/tɪŋ$_{55}$/ - /jɪŋ$_{55}$/	person	eagle
	47.	5.	咳 → 屈	/kʰɐt$_{5}$/ - /wɐt$_{5}$/	cough	bent
	48.	6.	波 → 囉	/pɔ$_{55}$/ - /lɔ$_{55}$/	ball	(particle)
	49.	7.	橋 → 療	/kʰiu$_{21}$/ - /liu$_{21}$	bridge	cure
fricative → sonorant	50.	1.	肺 → 餵	/fɐi$_{33}$/ - /wɐi$_{33}$/	lung	feed
	51.	2.	風 → 翁	/fuŋ$_{55}$/ - /juŋ$_{55}$/	wind	man
	52.	3.	心 → 陰	/sɐm$_{55}$/ - /jɐm$_{55}$/	heart	shady
	53.	4.	膝 → 屈	/sɐt$_{5}$/ - /wɐt$_{5}$/	knee	bent
	54.	5.	星 → 鷹	/sɪŋ$_{55}$/ - /jɪŋ$_{55}$/	star	eagle
	55.	6.	手 → 油	/sɐu$_{35}$/ - /jɐu$_{35}$/	hand	oil
	56.	7.	飯 → 爛	/fan$_{22}$/ - /lan$_{22}$/	rice	broken
affricate → sonorant	57.	1.	青 → 鷹	/tsʰɪŋ$_{55}$/ - /jɪŋ$_{55}$/	green	eagle
	58.	2.	床 → 黃	/tsʰɔŋ$_{21}$/ - /wɔŋ$_{21}$/	bed	yellow
	59.	3.	走 → 油	/tsɐu$_{35}$/ - /jɐu$_{35}$/	run	oil
	60.	4.	掣 → 餵	/tsɐi$_{33}$/ - /wɐi$_{33}$/	switch	feed
fricative → nasal	61.	1.	猴 → 牛	/hɐu$_{21}$/ - /ŋɐu$_{21}$/	monkey	cow
	62.	2.	鞋 → 涯	/hai$_{21}$/ - /ŋai$_{21}$/	shoe	cliff
	63.	3.	分 → 蚊	/fɐn$_{55}$/ - /mɐn$_{55}$/	divide	mosquito
	64.	4.	飯 → 慢	/fan$_{22}$/ - /man$_{22}$/	rice	slow
affricate → fricative	65.	1.	草 → 好	/tsʰou$_{35}$/ - /hou$_{35}$/	grass	good
	66.	2.	早 → 好	/tsou$_{35}$/ - /hou$_{35}$/	morning	good

II. Developmental Errors	**A. Aspiration Error**	**aspirated stop → unaspirated stop**	67.	1.	拍 → 伯	/pʰak$_{3}$/ - /pak$_{3}$/	clap	uncle
			68.	2.	抛 → 飽	/pʰau$_{55}$/ - /pau$_{55}$/	throw	bread
			69.	3.	聽 → 丁	/tʰɪŋ$_{55}$/ - /tɪŋ$_{55}$/	listen	person
			70.	4.	好天 → 好癲	/hou$_{35}$ tʰin$_{55}$/ - /hou$_{35}$ tin$_{55}$/	clear sky	'very crazy'
			71.	5.	曲 → 菊	/kʰuk$_{5}$/ - /kuk$_{5}$/	curly	Chrysanthemum
			72.	6.	小溪 → 小雞	/siu$_{35}$ kʰai$_{55}$/ - /siu$_{35}$ kai$_{55}$/	creek	'little chicken'
		aspirated affricate → unaspirated affricate	73.	1.	青 → 睛	/tsʰɪŋ$_{55}$/ - /tsɪŋ$_{55}$/	green	sunny
			74.	2.	葱 → 鐘	/tsʰuŋ$_{55}$/ - /tsuŋ$_{55}$/	onion	clock
	B. Place Preference	**Fronting (velar stop → alveolar stop, I/F)**	75.	1.	狗 → 豆	/kɐu$_{22}$/ - /tɐu$_{22}$/	dog	bean
			76.	2.	橋 → 條	/kʰiu$_{21}$/ - /tʰiu$_{21}$/	bridge	a strip
			77.	3.	三家 → 三打	/sam$_{55}$ ka$_{55}$/ - /sam$_{55}$ ta$_{55}$/	three families	three dozen
			78.	4.	塞 → 膝	/sɐk$_{5}$/ - /sɐt$_{5}$/	cork	knee
	C. Manner Preference	**Stopping (alveolar fricative → alveolar stop)**	79.	1.	星 → 丁	/sɪŋ$_{55}$/ - /tɪŋ$_{55}$/	star	person
			80.	2.	手 → 豆	/sɐu$_{22}$/ - /tɐu$_{22}$/	hand	bean
			81.	3.	青 → 聽	/tsʰɪŋ$_{55}$/ - /tʰɪŋ$_{55}$/	green	listen
		Affrication (alveolar fricative → affricate)	82.	1.	手 → 醜	/sɐu$_{35}$/ - /tsʰɐu$_{35}$/	hand	ugly
			83.	2.	星 → 睛	/sɪŋ$_{55}$/ - /tsɪŋ$_{55}$/	star	sunny
		Deaffrication (affricate → fricative)	84.	1.	青 → 星	/tsʰɪŋ$_{55}$/ - /sɪŋ$_{55}$/	green	star
			85.	2.	走 → 手	/tsɐu$_{35}$/ - /sɐu$_{35}$/	run	hand

	D. Syllable Structure	**Cluster Reduction (initial cluster → singleton)**	86.	1.	瓜 → 蛙	/kwa$_{55}$/ - /wa$_{55}$/	squash/melon	frog
			87.	2.	貴 → 餵	/kwɐi$_{33}$/ - /wɐi$_{33}$/	expensive	feed
			88.	3.	滾 → 搵	/kwɐn$_{35}$/ - /wɐn$_{35}$/	boil	search
			89.	4.	狂 → 黃	/k^{h}wɔŋ$_{21}$/ - /wɔŋ$_{21}$/	crazy	yellow
			90.	5.	誇 → 蛙	/k^{h}wa$_{55}$/ - /wa$_{55}$/	exaggerate	frog
			91.	6.	裙 → 雲	/k^{h}wɐŋ$_{21}$/ - /wɐŋ$_{21}$/	dress	cloud
III. Unexpected Errors	**A. Sibilant Distortion**	**labiodental fricative→ alveolar fricative**	92.	1.	肺 → 細	/fɐi$_{33}$/ - /sɐi$_{33}$/	lung	small
			93.	2.	翻 → 山	/fan$_{55}$/ - /san$_{55}$/	tomato	hill
			94.	3.	否 → 手	/fɐu$_{35}$/ - /sɐu$_{35}$/	no	hand
			95.	4.	買花 → 買沙	/mai$_{23}$ fa$_{55}$/ - /mai$_{23}$ sa$_{55}$/	buy flower	'buy sand'
			96.	5.	好房 → 好爽	/hou$_{35}$ fɔŋ$_{21}$/ - /hou$_{35}$ sɔŋ$_{21}$/	good room	very crunchy
	B. Aspiration Error	**unaspirated stop → aspirated stop**	97.	1.	飽 → 拋	/pau$_{55}$/ - /p^{h}au$_{55}$/	bread	throw
			98.	2.	丁 → 聽	/tɪŋ$_{55}$/ - /t^{h}ɪŋ$_{55}$/	grade D	listen
			99.	3.	吉 → 咳	/kɐt$_{5}$/ - /k^{h}ɐt$_{5}$/	mandarin	cough
			100.	4.	上釣 → 上跳	/sœŋ$_{35}$ tiu$_{33}$/ - /sœŋ$_{35}$ t^{h}iu$_{33}$/	'being	'up jump'
			101.	5.	可教 → 可靠	/hɔ$_{35}$ kau$_{33}$/ - /hɔ$_{35}$ k^{h}au$_{33}$/	teachable'	reliable
		unaspirated affricate → aspirated affricate	102.	1.	睛 → 青	/tsɪŋ$_{55}$/ - /ts^{h}ɪŋ$_{55}$/	eye	green
			103.	2.	走 → 醜	/tsɐu$_{35}$/ - /ts^{h}ɐu$_{35}$/	run	ugly
			104.	3.	鐘 → 葱	/tsuŋ$_{55}$/ - /ts^{h}uŋ$_{55}$/	clock	green onion
	C. Syllable Structure	**oral stop addition, I/F**	105.	1.	屋 → 菊	/uk$_{5}$/ - /kuk$_{5}$/	house	Chrysanthemum
			106.	2.	晏 → 誕	/an$_{33}$/ - /tan$_{33}$/	late	birth
			107.	3.	壓 → 八	/at$_{3}$/ - /pat$_{3}$/	pressure	eight
			108.	4.	餓 → 鱷	/ŋɔ$_{22}$/ - /ŋɔk$_{2}$/	hungry	crocodile
			109.	5.	霸 → 八	/pa$_{33}$/ - /pat$_{3}$/	dominate	eight
			110.	6.	駕 → 甲	/ka$_{33}$/ - /kap$_{3}$/	drive	nail

	Cluster Addition (singleton → initial cluster)	111.	1.	蛙 → 瓜	/wa$_{55}$/ - /kwa$_{55}$/	frog	squash/melon
		112.	2.	餵 → 貴	/wɐi$_{33}$/ - /kwɐi$_{33}$/	feed	expensive
		113.	3.	搵 → 滾	/wɐn$_{35}$/ - /kwɐn$_{35}$/	search	boil
		114.	4.	黃 → 狂	/wɔŋ$_{21}$/ - /k^{h}wɔŋ$_{21}$/	yellow	crazy
		115.	5.	蛙 → 誇	/wa$_{55}$/ - /k^{h}wa$_{55}$/	frog	exaggerate
		116.	6.	雲 → 裙	/wɐŋ$_{21}$/ - /k^{h}wɐŋ$_{21}$/	cloud	dress
D. Place Preference	**bilabial stop → alveolar stop**	117.	1.	給 → 咳	/kɐp$_{5}$/ - /k^{h}ɐt$_{23}$/	give	cough
		118.	2.	圾 → 殺	/sap$_{3}$/ - /sat$_{3}$/	trash	kill
E. Manner Preference	**sonorant → stop**	119.	1.	零 → 停	/lɪŋ$_{21}$/ - /t^{h}ɪŋ$_{21}$/	zero	stop
	sonorant → fricative	120.	1.	買轆 → 買粟	/mai$_{23}$ luk$_{2}$/ - /mai$_{23}$ suk$_{2}$/	buy wheel	‘buy corn’
	sonorant → affricate	121.	1.	零 → 晴	/lɪŋ$_{21}$/ - /ts^{h}ɪŋ$_{21}$/	zero	sunny
	nasal → stop, I/F	122.	1.	麵 → 便	/min$_{22}$/ - /pin$_{22}$/	noodle	convenient
		123.	2.	艦 → 立	/lam$_{22}$/ - /lap$_{2}$/	warship	stand
		124.	3.	拎 → 瀝	/lɪŋ$_{55}$/ - /lɪk$_{5}$/	carry	trickle
	stop → fricative	125.	1.	呔 → 徙	/t^{h}ai$_{55}$/ - /sai$_{55}$/	tie	waste
		126.	2.	豆 → 手	/tɐu$_{22}$/ - /sɐu$_{22}$/	bean	hand
	stop → affricate	127.	1.	停 → 晴	/t^{h}ɪŋ$_{21}$/ - /ts^{h}ɪŋ$_{21}$/	stop	sunny
F. Manner & Place Preference	**glottal fricative → stop**	128.	1.	好 → 圃	/hou$_{35}$/ - /p^{h}ou$_{35}$/	good	garden
		129.	2.	好 → 土	/hou$_{35}$/ - /t^{h}ou$_{35}$/	good	soil
		130.	3.	小熊 → 小窮	/siu$_{2}$ huŋ$_{21}$/ - /siu$_{2}$ k^{h}uŋ$_{21}$/	little bear	‘little poor’

sonorant → stop	131.	1.	黃 → 旁	/wɔŋ$_{21}$/ - /p^{h}ɔŋ$_{21}$/	yellow	'by the side of'
	132.	2.	餵 → 閉	/wɐi$_{33}$/ - /pɐi$_{33}$/	feed	close
	133.	3.	鷹 → 丁	/jɪŋ$_{55}$/ - /tɪŋ$_{55}$/	eagle	person
	134.	4.	麗 → 幣	/lɐi$_{22}$/ - /pɐi$_{22}$/	pretty	currency
	135.	5.	零 → 鯨	/lɪŋ$_{21}$/ - /k^{h}ɪŋ$_{21}$/	zero	whale
sonorant → fricative	136.	1.	狼 → 房	/lɔŋ$_{21}$/ - /fɔŋ$_{21}$/	wolf	flat

Notes to Appendix B.

1. Sibilant distortion: a sibilant is produced at a different place of articulation (e.g. alveolar fricative to labiodental fricative: /san$_{55}$/ - /fan$_{55}$/).

2. Manner preference: a change of manner of articulation was used in the realization of the target sound (e.g. stop to nasal: /pau$_{55}$/ - /mau$_{55}$/).

3. Place preference: the target sound was articulated at a different place of articulation (e.g. alveolar to bilabial: /t^{h}ɪŋ$_{21}$/ - /k^{h}ɪŋ$_{21}$/).

4. Manner and place preference: a combination of manner and place errors was used (e.g. labiodental fricative to alveolar liquid: /fan$_{22}$/ - /lan$_{22}$/).

5. Aspiration errors: an aspirated target was used instead of its unaspirated counterpart or vice versa (e.g. aspirated to unaspirated: /p^{h}ak$_{3}$/ - /pak$_{3}$/).

6. Syllable structures: a consonant was either reduced or added to the target (e.g. stop to null: /pa$_{55}$/ - /a$_{55}$/).

Appendix C

Sample Listening Response Form

	Circle one		OR If different, transcribe the target phoneme heard.	AND Circle one	If can't identify any, circle "**?**".
1.	豆 /t̲ɐu$_{22}$/	鈕 /n̲ɐu$_{22}$/		Clear Distorted	?
2.	靠 /k̲^{h}au$_{33}$/	坳 /au$_{33}$/		Clear Distorted	?
3.	葉 /jip̲$_{2}$/	易 /ji$_{22}$/		Clear Distorted	?
4.	想爸̲ /sœŋ$_{35}$ p̲a$_{5}$/	想鴉̲ /sœŋ$_{35}$ a$_{55}$/		Clear Distorted	?
5.	鴉 /a$_{55}$/	爸 /p̲a$_{55}$/		Clear Distorted	?
6.	床 /t̲s̲^{h}ɔŋ$_{21}$/	黃 /w̲ɔŋ$_{21}$/		Clear Distorted	?
7.	狼 /l̲ɔŋ$_{21}$/	房 /f̲ɔŋ$_{21}$/		Clear Distorted	?
8.	水 /s̲ɵi$_{35}$/	女 /n̲ɵi$_{35}$/		Clear Distorted	?
9.	蛙 /w̲a$_{55}$/	瓜 /k̲w̲a$_{55}$/		Clear Distorted	?